Vol. 13, No. 9 September, 1957

LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

JOURNAL OF THE AMERICAN SOCIETY OF LUBRICATION ENGINEERS

Farval works in Africa, too—lubrication time reduced 93%, grease use cut 83%

FARVAL—
Studies in Centralized Lubrication
No. 202

● Here at a copper mine in Northern Rhodesia, Farval systems were installed on power shovels used to remove overburden. Not only have bearings been protected fully by adequate lubrication, but the time and lubricant savings reported are beyond expectation.

Time required for lubricating shovels has been reduced from two hours per shift to only eight minutes — a 93% reduction. Grease consumption has been cut from 400 pounds per month to only 70 pounds—a saving of 83%.

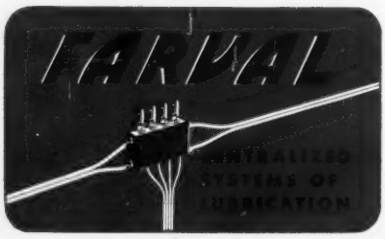
Farval Centralized Lubrication proves its value in scores of mining operations like this—remote from repair shops and supply centers, where economy and dependability pay real dividends.

Find out how Farval can help you. Write for Bulletin 26-S, newly revised presentation of the features and advantages of Farval Centralized Lubrication, complete with engineering data on all types of systems. The Farval Corporation, 3267 E. 80th St., Cleveland 4, O.

Affiliate of The Cleveland Worm & Gear Company, Industrial Worm Gearing. In Canada: Peacock Brothers Limited.

KEYS TO ADEQUATE LUBRICATION—
Wherever you see the sign of Farval—familiar valve manifolds, dual lubricant lines and central pumping station—you know a machine is being properly lubricated.

Inset above shows Farval lines and valves mounted on shovel undercarriage.



LUBRICATION ENGINEERING

RESEARCH APPLICATION EDUCATION MAINTENANCE

Volume 13, No. 9

September, 1957

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COVER PICTURE: Testing the rust preventive characteristics of lubricants. One month of this test, in which a warm mist containing four percent salt is sprayed over small steel panels coated with the lubricant under test, is equal to a year's exposure to sea atmosphere. (Photo courtesy Gulf Oil Co.)

Abstracted by Engineering Index

LUBRICATION ENGINEERING is published monthly by the American Society of Lubrication Enginers, 84 E. Randolph St., Chicago 1, Illinois. Current volume single copies 75c. Copies of issues from previous volumes $1.00, if available; Copies to Foreign addresses add 50c per copy. Annual Subscription $6.00 in the USA and Canada, $7.00 to all other countries.

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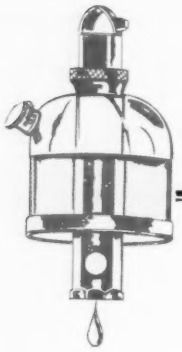
The Sight Glass



Highlights of Articles Scheduled for Coming Issues!

A Threading Test for Cutting Oil Evaluation

The evaluation of cutting oils has been debated wherever lubrication engineers congregate. Many methods, while adequate in establishing a general rating, fail to correlate the evaluated rating with field experiences in the plant. The laboratory test described is based on measurement of the torque required to cut a thread. Several valuable tables dealing with machinability of various materials and the effects of pitch, speed, and diameter or threading torque are included.

Apparent Adsorption Isotherms of Oleic Acid from Hydrocarbons as Obtained from Coefficient of Friction Measurements

Effective lubrication under conditions of boundary lubrication is a continuing subject of research by many leading scientists as more emphasis is placed on monomolecular films. This paper describes the measurement of dilute solutions of oleic acid in a hydrocarbon at various temperatures. Behavior of these solutions as a function of temperature is described and the authors relate this behavior to the adsorption of a monomolecular film. The work is a part of the program of the Association of American Railroads analysis of "hot boxes."

A Lubrication Engineer Surveys Steel Mill Gearing—Part I.

In spite of the progress made in developing new lubricants for heavy duty operation of gears, serious problems of gear failure and overloading are encountered in the steel industry. Differences among criteria for the design of gears for steel mills has been partly responsible for gear failure — incomplete information on failure incidence and causes must also be blamed.

Steel Mill Gearing—Part II.

Predictions of wear and dynamic loading from formulas developed in part one of this paper are applied to actual gearing situations to determine what correlation exists as a basis for decreased gear failure.

LUBRICATION IN THE NEWS

Institute to Compile Full Lithium Report

The newly-formed American Lithium Institute has been named by the Wright Air Development Center as the compiler of all available data on lithium and its compounds.

Marshall Sittig, president of the Institute, will be in charge of the project, which will investigate, analyze, and consolidate physical, mechanical and chemical data. In the investigative phase of the project, pertinent material on lithium will be extracted and compiled with source references. The analytical phase will be a critical examination of the collected data—and the facts will be compiled in a comprehensive handbook.

The Institute, a non-profit organization, was formed earlier this year to broaden present markets for lithium and lithium compounds, and develop new markets through sponsorship of research and dissemination of information.

R.R. Fuel and Lube Bill Hits All-Time High

CHICAGO — The fuel and lubricant bill of the nation's railroads exceeded the half-billion dollar mark in 1956, reports the Association of American Railroads. C. R. Jensen, chairman of AAR's Petroleum and Coal Committee, said that railroad expenditures for petroleum products and coal last year totaled $522,647,000, an increase of five per cent over 1955.

Additionally, Class I railroads spent over $45 million for lubricating oils, greases, boiler compounds, and related products, bringing the total sum spent by railroads within the oil industry last year to more than $445 million.

New Hypoid Gear Lube Seen Multi-Purpose Lubricant Replacement

Developed by the American Petroleum Institute, a new type gear lubricant with increased load-carrying ability is expected to supersede present multi-purpose gear lubricants of the MIL-2105 level in military and civilian use. Designed for greater protection of hypoid gears in sustained high-speed and high-torque service, the new lubricant has been designated MultiPurpose Type Lubricant (API Service GL-4) by the Society of Automotive Engineers. It is anticipated that this designation will be used in 1958 passenger car manuals in the event of the product's widespread adoption.

PRACTICAL LUBRICATION:

Extending Soluble Emulsion Life

Adding sodium compounds to cutting oil emulsions may be the answer to short solution life due to bacterial decomposition, say Dow chemical engineers. Disposal of soluble oil each week-end has long been common practice . . . because decomposition causes the emulsion to break, and the oil to putrefy.

Naturally, because of the high cost of coolants, their use for longer periods than the usual week before decomposition sets in is an important element in machine shop economy.

Sodium orthophenylphenate, claim the engineers, will solve this problem.

Emulsifiable oil concentrates that do not contain a preservative are practically free of bacteria when first put into use. But as soon as the oil concentrate is added to water, the resulting emulsion becomes susceptible to bacterial attack. This is most noticeable the following week after the machines have been idle over the week-end. Unwelcome too is the acid by-product of decomposition which stains metal parts and detracts from the lubricity of the emulsion.

Addition of the sodium compound, manufactured by Dow under the trade name "Dowicide A" will provide effective protection against bacteria in soluble oil emulsions, it is claimed. Recommended addition is one pound of the preservative to 100 gallons of emulsion, providing a concentration of 0.12 per cent. A concentration of from 0.10 to 0.15 per cent is mandatory for good bacterial control. This ration is said to prevent breakdown of the emulsion for extended periods, including those when machines are inoperative.

A booklet on the preservation of soluble oil emulsions will be provided free by writing to Dowicide Sales, the Dow Chemical Co., Midland, Mich.

MEMO:

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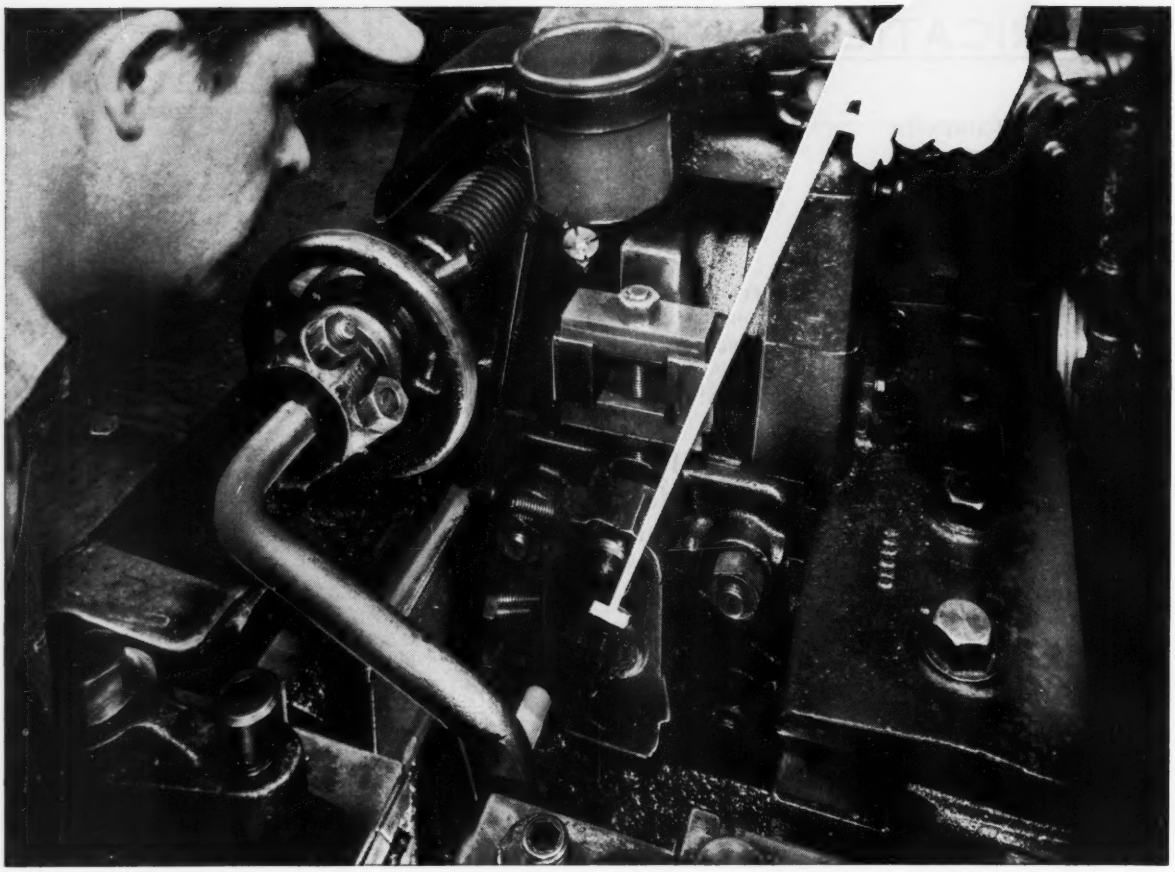
A Touch here does so much



COOL PROFITS FROM HOT HEADS

A touch of 'dag'® 200 on the punch that sinks hexagonal recesses in steel screwheads increases efficiency 40%, doubles production, and improves quality. Two operations and a bulky machine are eliminated, and 42 square feet of floor space gained per machine. Life of the hex punches is extended over 500%.

Before using 'dag' 200, the die in the hammer head seized and pulled out when punched into the white hot blank, resulting in costly rejects and downtime. The unique properties of 'dag' 200, a dispersion of molybdenum disulfide, keep the hammer slamming 2,500 blanks per die — six times more than before. Three hours' downtime is saved per die, and only two-and-a-half gallons of 'dag' 200 are needed to produce 21,000 units.

This is only one of the many Acheson colloidal dispersions which keep things moving fast in hundreds of industries. Talk with your Acheson Service Engineer soon, and write for Bulletin 426, Metalworking Applications. Address Dept. LE-9.

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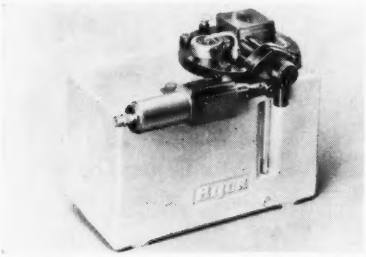
New Products

HI-PRESSURE LUBRICATOR

A hydraulic lubricator for use in applications where desired lubricant discharge per machine cycle is relatively small is now



available. Designated Cyclic "Y", the lubricator will operate on any hydraulic line pressure from 500 psi to 300 psi and will deliver 2 cc. of oil per lubricating cycle. By resetting hydraulic piston stroke adjustment any one of seven different lubrication cycles can be obtained. Reservoir capacity is 6 pints. In operation, hydraulic pressure drives a piston connected to the ratchet arm. The hydraulic piston is returned by a spring within the cylinder. Seven different settings of the hydraulic piston stroke are provided. These settings determine the number of hydraulic strokes or machine cycles required for one lubricator cycle. A small hole is drilled through the hydraulic piston to bleed a small amount of oil on the pressure stroke, thereby cushioning the shock of operation at high pressures. The rod packing is Palmetto GT Ring No. 6053, a synthetic "T" shaped ring supported on both sides by phenolic rings which prevent the packing from being squeezed into the clearance around the piston rod.

For further information on the "Cyclic Y" Lubricator, write "Service," Bijur Lubricating Corp., 151 W. Passaic St., Rochelle Park, New Jersey.

SYNTHETIC RUBBER PACKING

Approval by the Underwriters' Laboratory, Inc. of a synthetic rubber packing and O-ring compound that meets requirements for use with gasoline, kerosene, LPG and fuel oils numbers 1 through 6 has been announced by E. F. Houghton & Co., 303 W. Lehigh Ave., Philadelphia 33, Pa., developers of the material.

NON-FLAMMABLE GREASE

A non-flammable grease with no melting point is now available for applications where flame-proof lubrication is necessary. The grease is water-proof and has extreme pressure characteristics, capable of lubricating under very high temperatures and highly loaded bearings. For additional information on Belco No-Flame grease, write Bel-Ray Co., Inc., Madison, N. J.

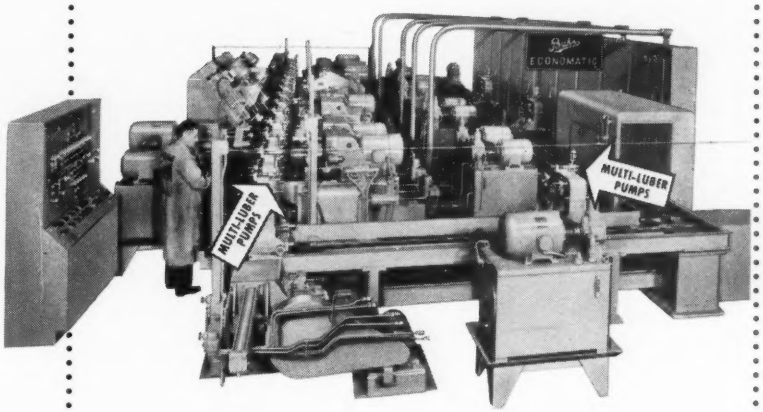
Lincoln Multi-Luber*

POWER LUBRICATION SYSTEMS

for automated machine groups and components

End lubrication down-time...

Reduce operating costs



55 DIFFERENT OPERATIONS EVERY 22 SECONDS... and not one second of down-time for lubrication

All moving parts on this automated Buhr Economatic, including fixtures, are automatically lubricated at predetermined intervals by a Lincoln Multi-Luber Centralized Power Lubrication System. Costly down-time for lubrication is eliminated, along with excessive bearing wear and breakdowns due to inadequate lubrication.

Engineered for Positive, Reliable Lubrication

Lincoln Multi-Luber Systems are especially designed and engineered to keep pace with high rates of production, to save valuable man-hours, and eliminate needless repairs. A premeasured film of refinery pure lubricant is automatically applied to bearings at predetermined, self-controlled time intervals. On existing facilities and new equipment, these Systems provide a tested, low-cost method that improves production efficiency, lengthens service-life, and reduces operating costs.

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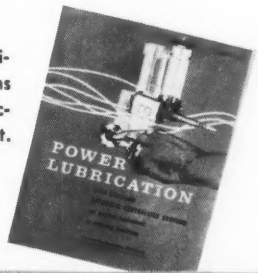

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New Products

TUBING FITS INDIVIDUAL NEEDS

Spaghetti tubing—both thin and standard walls, flexible tubing and rod and heavy wall tubing made from "Teflon' is cut in

lengths to meet individual requirements for aviation, electronic, electrical, automotive and general industrial applications. The spaghetti, tube and rod are production cut clean and square without feathers or flattening to a high degree of accuracy to any length from ¼ inch up. This service is said to save time and material for the user as assembly is made easier with ends not flattened. For full details, write Pennsylvania Fluorocarbon Co., 1115 N. 38th St., Philadelphia 4, Pa.

NEW CUTTING OIL DEVELOPED

Gulfcut, an emulsified cutting oil, which substantially increases the efficiency of many heavy-duty machining and grinding operations has been developed. Six years of research and development are behind this new product which reportedly makes possible lower machining costs through longer tool life, heavier cuts, and higher speeds and feeds. These user benefits apply to all metals, particularly those with low machinability ratings. In grinding operations, in particular, the new product is said to give exceptional results, with good finishes and minimum wheel loading and breakdown. During field testing of this new product, which contains 9 major components, mixtures ranged from 5-1 to 150-1. Average mixture is 25 parts water and one part soluble oil. Applications include: Heavy hogging cuts, fast fine cuts, boring and grinding of ferrous and nonferrous metals and alloys, including tough titanium alloys.

LOW-MELTING ANTIOXIDANT

An entirely new low melting antioxidant, known as AC-6, which when used in low concentrations reportedly provides effective and economical protection against oxidative degradation at high temperatures in polymeric materials, has been made available for the first time in pilot plant quantities. The low melting range of Catalin Antioxidant AC-6 facilitates its incorporation into products such as polyethylene, petroleum hydrocarbons, rubber, impact grades of polystyrene, waxes and other materials in which high temperatures are a factor in processing and end use. The antioxidant also exhibits outstanding nonstaining and non-discoloring properties. Complete data and laboratory samples are available from Catalin Corporation of America, One Park Avenue, New York 16, New York.

GAS CHROMATOGRAPH GIVES QUICK, ACCURATE RESULTS

Reportedly providing quick and accurate analysis of gases and liquids with boiling points up to 350° C, a new gas chromatograph utilizes a tubular column packed with a material which separates components by passing them through the column at different rates. Applicable for research, quality control, and other analytical problems, the instrument should prove useful in many fields. For additional information, write for Bulletin 711 to Scientific Instruments Div., Beckman Instruments, Inc., Fullerton, Calif.

BATTERY OPERATES 9-POUND ONE-KNOB CORROSION METER

A new single knob control, battery-operated corrosion tester is suitable for corrosion testing in chemical plants, determin-

ing inhibitor characteristics for oils and gasolines, and testing effectiveness of cathodic potential protection devices. With battery operation, the "Corro-Dex" can be used successfully in field or laboratory. It weighs nine pounds and comes in an aluminum carrying case 9" x 9" x 6" with carrying strap and hinged cover. The meter is equipped with a full transistor type, shock proof circuit. Write for Bulletin #5205 to Labline, Inc., 3070-82 W. Grand Ave., Chicago 22, Ill.

BENTONE* 34

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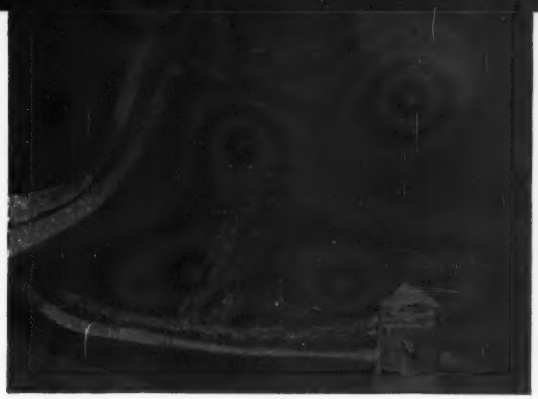

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1. Will not melt.
2. Repels water.
3. Adheres to metal.
4. Pumps easily.
5. Less consumption.

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FOR MULTI-PURPOSE GREASE

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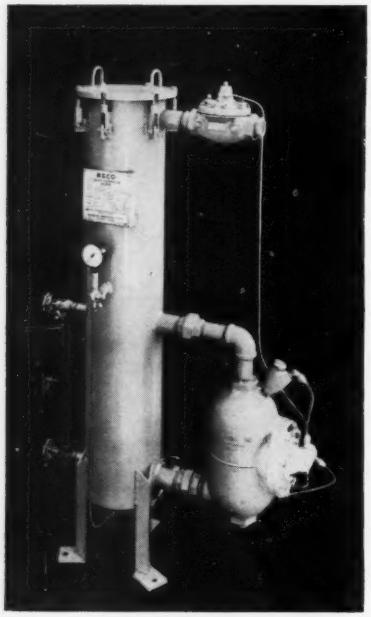
For additional information contact your local supplier as listed on adjoining page or write

NATIONAL LEAD COMPANY • BAROID DIVISION
P. O. BOX 1675 HOUSTON 1, TEXAS

New Products

FILTER-SEPARATOR ADAPTS FUEL FILTERING PROCESSES

A new rugged filter-separator of the replaceable-cartridge type reportedly will remove condensed water, water-borne contaminants and solids from fuels, oils, solvents and other oleaginous liquids at flowrates of from 5 to 40 gallons per minute



with 100 per cent effectiveness. It is also suitable for a wide variety of aqueous solution treatments. The unit stands vertically on one square foot of floor space, and has 1¼ inch horizontal inlet and outlet connections at 3 inches and 52 inches from the floor. Rated at 15 gpm, the new RECO unit will handle light fuels like gasoline at from 30 to 40 gpm, kerosenes and jet fuels at 20 to 25 gpm, and heavy diesel fuels at 10 gpm. For further information, write to: J. Warren Robinson, Filter Products Division, Richmond Engineering Company, Seventh and Hospital Streets, Richmond 5, Virginia.

NEW GREASE ADDITIVE

A new synthetic gelling agent for industrial greases is said to make possible formulation of superior multipurpose and specialized grease lubricants. GA-10, a derivative of the miracle fiber ingredient, terephthalic acid, was first developed to meet demand for grease lubricants that would stand up under the extreme temperatures, high loads, and high speeds of modern machinery. Greases normally made with the sodium salt of the new product reportedly show good heat stability, water resistance, work stability and bearing performance. For further information, consult Oronite Chemical Co., 200 Bush St., San Francisco, Calif.

CONVERSION CHART FOR HARDNESS VALUES

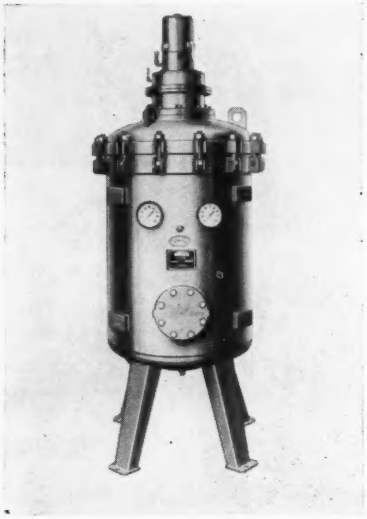
A desk-size chart containing conversion data for Rockwell tests and other hardness scales is available from The Torsion Balance Company, Clifton, New Jersey. In addition to hardness conversion, this chart also has tables for cylindrical corrections.

FILTRATION PROCESS ANALYZER

Dynamics Research Associates' Report No. 66-R8 describes the Dynateq R-8 filtration process analyzer, designed to automatically measure and record weight, weight rate, and data required to determine plugging value of viscose. Report No. 66-R8 can be obtained from the instrument's designers—Dynamics Research Associates, div. of Universal Match Corp., P. O. Box 5841, Ferguson 21, Mo.

SELF-CLEANING FILTER HAS INTERCHANGEABLE ELEMENTS

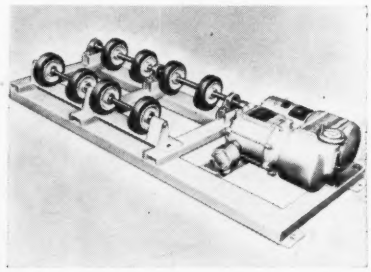
A dual purpose, automatic filter with interchangeable elements designed for lubricants and coolants is now available. Both



types of elements are interchangeable within the filter case. An interval repeat timer provides automatic self-cleaning and permits adjustment of cleaning cycle length from a 20 second minimum to a 30 minute maximum. According to the manufacturer, exceptionally long filtration cycles are possible with an extra large sump located below the filtering units. A four-page bulletin giving complete specifications can be obtained by writing Bowser, Inc., Lubrication and Filtration Div., 1300 E. Creighton Ave., Fort Wayne, Ind.

VARIABLE SPEED ROTATOR

A stationary drum rotator, engineered for variable speed rotating equipment, has been developed for blending, tumbling, and



mixing. Designed to handle loads from 500 to 1000 lbs., the rotator has an all-welded steel frame—24" x 65"—made of 3" 5 lb. cross channels, and 5" 9 lb. horizontal channels. Four lugs are provided to secure the unit to floor or similar base. For further information on Model 1-5154VS stationary drum rotator, write to Morse Mfg. Co., Inc., 727 W. Manlius St., East Syracuse, N. Y.

FELTED ORLON AVAILABLE

Chemically shrunk Orlon felts are now available on a commercial basis. Currently being manufactured in weights ranging from eight ounces to eight pounds per square yard, these felted Orlon materials are available for use in many of the applications formerly filled by woven Orlon structures based on continuous filament yarn which is no longer commercially available. Further information can be obtained from American Felt Co., Glenville, Conn.

MATERIAL WITHSTANDS IMPACT

A new bearing material has been developed for applications where lubrication is a problem. This composite material is recommended for dry bearing services, both sliding and rotating, at temperatures up to 500 degrees F. Because of its properties, it reportedly works excellently with solvents such as acetone and other corrosives. Since no permanent shock deformation will occur, the material is suited for applications subject to impact, an important factor in mechanical linkage assemblies where constant vertical and horizontal impact is present. The material has a static or kinetic coefficient of friction against polished steel of only 0.04 and a P.V. factor up to 10,000, withstanding speeds up to 1000 rpm. and loads to 100 psi. For full information regarding Chemloy, contact Crane Packing Co., Dept. LEC, 6400 Oakton St., Morton Grove, Ill.

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1. Better Lubrication — Less Machine Down Time

MICRO-FOG lubrication automatically coats all the bearings, gears, chains and other components of a machine with a continuous, protective film of clean oil. Just the right amount of oil is applied to provide the most efficient lubrication, reducing wear on machine components, and cutting maintenance and replacements costs.

2. Oil Always Fresh, Always Clean

There is no recirculation of deteriorated or contaminated lubricant to cause wear or corrosion. Clean oil is applied continuously to all lubrication points in carefully metered amounts.

3. For Large and Small, Plain and Anti-Friction Bearings

MICRO-FOG Lubricating systems have found enthusiastic acceptance for use on all types of machinery, ranging from *high speed* grinders to huge roll mill bearings on shafts as large as 34" in diameter and turning at relatively *low speeds*.

4. Centralized, Automatic Lubrication

A single, MICRO-FOG Lubricator will automatically deliver enough airborne lubricant, proportionately distributed to completely lubricate even a large machine tool. Only one lubricator to maintain and refill.

5. Big Savings in Lubricant

Carefully metered quantities of oil are applied to each lubrication point. MICRO-FOG provides more thorough lubrication using only a few ounces of oil per day than other methods using several gallons of oil per day.

6. Bearings Run Cooler

Air passing through the bearing carries away heat, and there is no pool of lubricant in the bearing to generate heat as a result of fluid friction. Lubrication is continuous — there are no periods of insufficient lubrication with metal wearing on metal.

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- CHAINS
- SLIDES
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- OTHER MACHINE COMPONENTS

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A slight positive pressure is maintained within the bearing, and air continuously escapes from the bearing, preventing the entrance of contaminants from the surrounding atmosphere.

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Because MICRO-FOG must be vented to the atmosphere, it is not necessary to maintain tight seals. Fewer oil seals are required, reducing maintenance and machine down-time.

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The quantity of lubricant used in MICRO-FOG Lubrication System is so small that there is nothing to reclaim or recirculate. Expensive high pressure piping is also eliminated.

10. Automatic Alarm Controls

MICRO-FOG Lubricators are available with switches to actuate an alarm system or controls as a warning of conditions affecting proper lubrication.

11. Visible Oil Feed

The oil feed is readily visible on all models of MICRO-FOG Lubricators, providing positive proof that the lubricator is operating properly.

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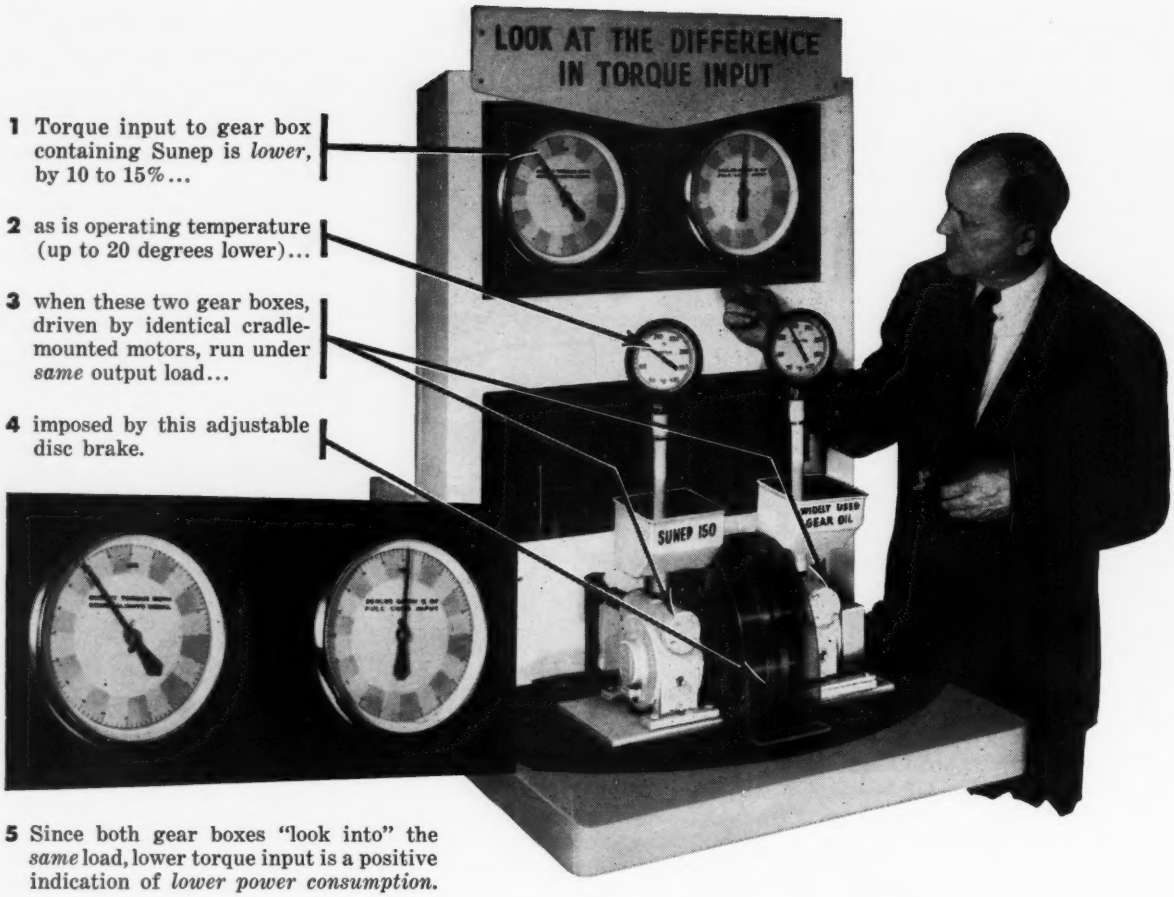
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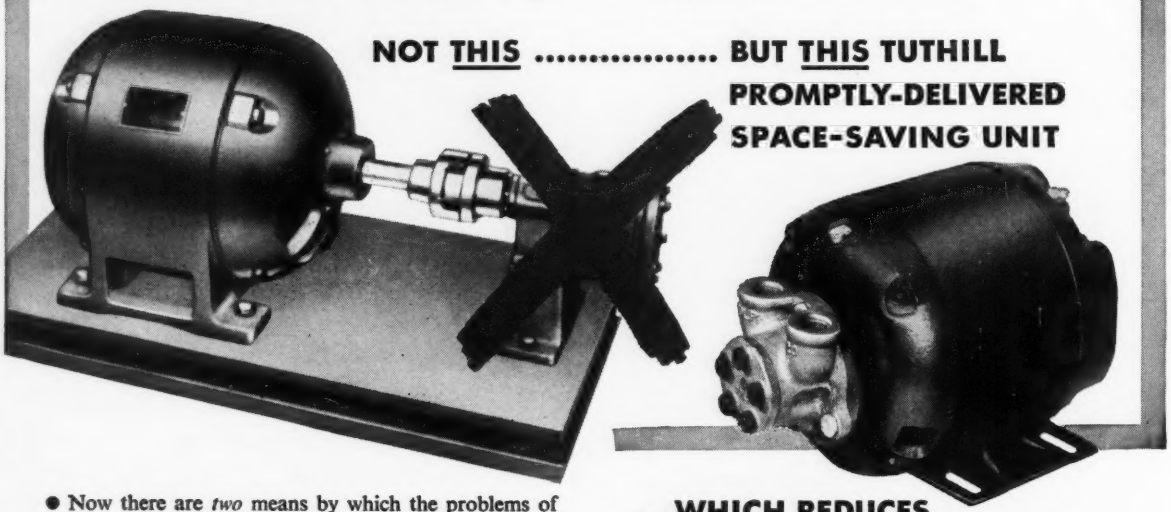

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First, the use of compact, custom-built TUTHILL "POWERMITE" pump-and-driving-motor units for original equipment manufacturers having QUANTITY requirements.

Second, the use of compact, standard, promptly-available TUTHILL pump and driving motor units *for individual applications which do not warrant custom design.*

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PUMPS FOR YOUR PURPOSE

ASPERITIES... *a page of editorial comment and opinion*

USEFUL LABOR

The other day I took occasion to re-read what I consider to be a classic in literary common sense: Dr. C. F. Kettering's address delivered at the 1952 Annual Banquet of the American Society of Mechanical Engineers on "The Engineer's Responsibility in Educating the Public." Today, in view of the reported shortage of technical people and students studying for the technical field, it is particularly timely to reconsider Dr. Kettering's remarks. They may bolster the morale of the oldster who possibly has been retired from active service. There is still a niche for him and his technical knowledge but he must do some of the carving for himself. How? There are a number of ways. For example:

He could become interested in the Junior Achievement activity.

He could show more interest in Boy's Club, Little League and Scouting.

He could ascertain where, in his own community he might be able to fit into the science or mathematics branches of the secondary school system.

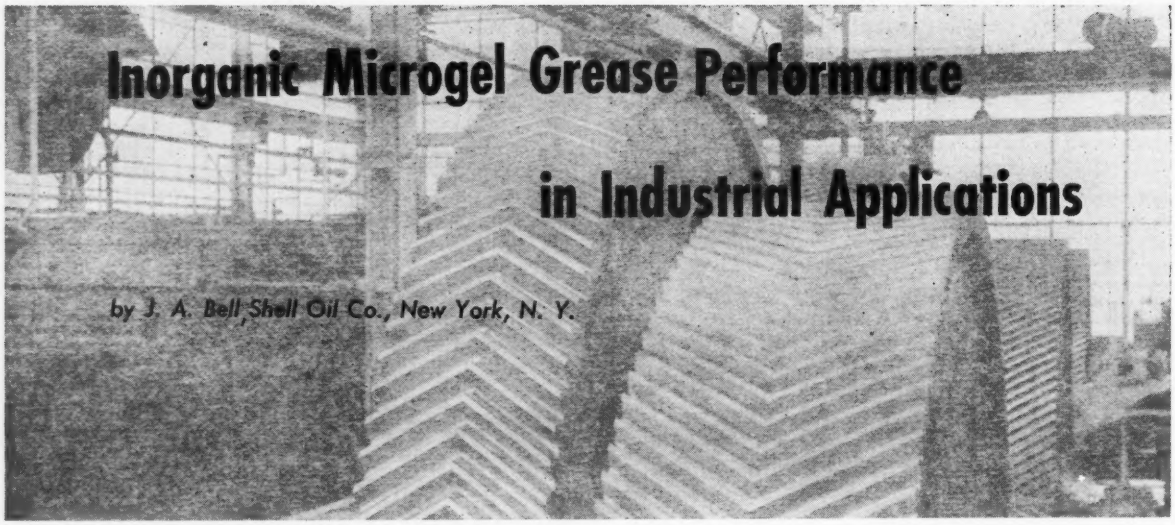
To be sure, he may not have a teaching certificate; possibly he would shy away from a refresher course to obtain one. But would he need such a certificate to function as a volunteer or special lecturer or laboratory counselor? Perhaps not.

Let's see how this all ties in with useful labor for himself and stimulated interest of the youngsters in chemistry and engineering. In his technical life he has doubtless had something to do with research or testing laboratory work. He has learned the value of developing significant data by the process of comparison. This idea of comparison is interesting. Possibly it can explain why some youngsters with potential technical ability shy away from the studies required. Somehow they have gathered the idea that the scientist, chemist or engineer is a "brain", sort of a superman in a world where they could not hope to compete. We need to disillusion them, to bring their thinking down to earth. The oldster who himself has been disillusioned is an excellent candidate for the job of portraying science and chemistry in a simple factual manner.

Any kid who can rebuild an old model car into a hot rod is a prospective engineer. Often, however, one look at trigonometrical symbols, a differential or integral sign, or a chemical formula scares him into economics or some general course where there is seemingly less mystery. As Dr. Kettering said, however: "It isn't nearly as bad as it looks — let's tell them that there is only about 10 percent of engineering that can be calculated and the other 90 percent has to be done by experimental work".

Junior did just this when he rebuilt his hot rod. If those of us who built far more simple gadgets in our time will tell the kids of today the simple facts of life about mathematics, chemistry and science, the exciting future ahead of them will unfold when these facts are understood.

A. F. BREWER
Consulting Editor.



Inorganic Microgel Grease Performance in Industrial Applications

by J. A. Bell, Shell Oil Co., New York, N. Y.

For a quick, cross-industry look at comparative performance, refer to opposite page:

The need for improved industrial multipurpose greases and the development of an inorganic microgel grease of this type are briefly reviewed. Comparative laboratory evaluation test data are presented to illustrate gel grease. Its performance is compared with other greases in a wide range of industrial applications. These evaluation studies show the microgel grease is superior to lithium base multipurpose greases in temperature ceiling and effective operational life under both dry and wet conditions. It is concluded that this development considerably broadens the versatility and scope of the industrial multipurpose type grease.

DURING the past decade or so both grease manufacturers and consumers have shown increasing interest in the multipurpose type of grease. Experience substantiates that the multipurpose concept is basically sound and practicable. Many excellent greases of this type are available today which, in varying degree, function over a broad range of operating conditions and applications.

However, unit cost of labor used to apply lubricants, as well as to maintain and repair equipment, is increasing steadily. On the other hand, stepped-up production schedules and steady technological advances in industry frequently impose greater demands on the lubricant. This situation provides incentive to seek improved lubricants which can materially assist in lowering, or at least stabilizing, lubrication and maintenance costs. Consequently, the lubricating grease industry is constantly striving to increase versatility and effective operational life of the multipurpose type grease. Obviously, there are various approaches to this basic problem. This paper illustrates what is being accomplished in this direction with a new inorganic microgel multipurpose grease.

BASIC PROPERTIES

The basic principles governing the properties of inorganic microgel greases and some of the fundamental studies leading to the development of this specific product were reviewed and discussed in a previous paper(1).

Before proceeding to discuss the properties and field performance of this new multipurpose grease, one or two general comments might be in order. Just as soap type greases are classified broadly as calcium base, sodium base, lithium base, etc., so the inorganic microgel greases are frequently referred to as clay base, silica base, etc. However, it is well known that the properties of a soap type grease are determined not only by the metal base, but also by the particular acids combined with the metal to form the soap. Similarly, processing conditions can modify the physical characteristics of the soap phase and, consequently, the properties of the grease. The type of oil used and choice of additives to enhance or impart specific properties also play a part in determining the over-all performance level of the lubricant. The same situation exists in the case of the inorganic microgel greases. The clay or silica base is merely a foundation on which to build. Only the proper combination of microgel, surfactant, processing methods, oil and additives can give optimum results.

LABORATORY EVALUATION TESTS

Lithium base multipurpose greases appear to have enjoyed the widest acceptance to date. Consequently, they provide a familiar and convenient yardstick to measure the potential merits of new multipurpose greases. In Table III, the general properties of this new inorganic microgel grease are compared with those of a well established lithium base multipurpose grease. Both greases have an NLGI No. 2 consistency, contain a 500 S. S. U. at 100°F mineral oil, and appropriate oxidation and corrosion inhibitors. It is believed these data are self-explanatory and need not be reviewed in detail. They show that, in some respects, there is little to choose between the two greases. In others, a marked difference exists, but in no significant property is the microgel grease inferior. A qualitative comparison of the greases might be summarized as

(1) Peterson, W. H., Accinelli, J. B. and Bondi, A., Nature and Performance of Some Inorganic Base Greases, Lubrication Eng., Vol. 12, N/2, 1956, 95-101.

(DRY APPLICATIONS) TABLES I - Ia

INDUSTRY	EQUIPMENT	GREASE APPLICATION POINT*	SERVICE CONDITIONS		PREVIOUS GREASE		SERVICE EXPERIENCE WITH NEW INORGANIC MICROGEL GREASE
			TEMP. °F.	OTHER	TYPE	PERFORMANCE	
CHEMICAL	Gear-drive Flexible Couplings (Chlorine compressors powered with steam turbines)	Gears	Moderate	Continuous. 3½" shaft 7200 RPM.	Lithium Base Multi-Purpose	Compressor units inspected for routine maintenance every 6 months. Grease in couplings invariably showed considerable hardening due to excessive oil separation. Although no failures occurred margin of safety considered inadequate.	On same 6 month relubrication cycle shows little change in consistency. Lubrication excellent and ample margin of safety.
STEEL	Sinter Machine	Pallet Wheel Bearings	200/225	Continuous, very dusty.	Clay Base	Deteriorated in 6 months to point where wheels "froze" and pallets had to be removed to clean and relubricate bearings.	After 6 months lubricant and bearing condition excellent necessitating only small addition of grease to hub cap while continuing operation of unit. After additional 6 months wheels still turned freely. Power consumption, bearing wear and replacement reduced.
TEXTILE (Carpets)	Oven for curing rubber backing	Roll support bearings (inboard)	270/300	Intermittent	Lithium Base Multi-Purpose	Satisfactory on weekly lubrication cycle.	Lubrication cycle extended to 3 weeks.
METAL WORKING	Wire Drawing Machine (Tungsten)	Various bearings	300	Continuous	Lithium Base Multi-Purpose	Satisfactory on daily lubrication cycle.	Lubrication cycle extended to 7 days.
CERAMIC (Brick)	Tunnel Kiln Cars	Wheel Bearings	330 Max.	Drying and Firing Cycle 126 hours.	Silicone ($7.30 pound)	In view of cost only applied to bearings i.e. 4-5 ozs. per wheel. On 60 day lubrication cycle bearing failures averaged 2 a day out of a total of 1200 bearings (150 cars).	With wheel bearing assemblies fully packed (approx. 4 lbs. grease) cars operating 12 months minimum without interim lubrication. Bearing failure eliminated.
STEEL	Ingot Buggies	Tilt Bearings (Bronze)		Continuous. High temp. and shock loads.	Clay Base and High Melting Point Calcium Base	On 8 hour lubrication cycle deterioration of grease resulted in high rate of bearing failures.	Bearing failures eliminated on same lubrication cycle.
CEMENT	White Clinker Drier	Grate eccentrics (Steel/C. I.) and support wheels (Bronze Bushing)	250/425 Depending on location	Continuous, very dusty.	Lithium Base Multi-Purpose	Frequent lubrication required due to poor retention and necessity to flush out cement dust.	Better retention and ability to form "Grease Seal" permitted extending lubrication cycle and reducing quantity of grease delivered per cycle. Grease consumption reduced from 400 pounds to 100 pounds a week.
METAL WORKING	Heat Treat Buggies (Aluminum Extrusions)	Swivel Castor Bearings	450	Furnace soak period 2-8 hours, static.	Various (none satisfactory)	Application of graphited-oil before each trip appeared best compromise. However after two trips or so castors frequently "frozen" necessitating cleaning of bearings.	"Frozen" castors and cleaning of bearings eliminated with a lubrication cycle corresponding to an average of 6 trips.
ELECTRIC POWER PLANT	Induction Fans on Boilers	Damper Bearings		Continuous. Exhaust gases approx. 900°F.	Clay Base High Melting Point Calcium Base	Unsatisfactory on weekly lubrication cycle due to:— Carbonisation Formation of "Dry powdery" residues	Lubrication quite satisfactory on same lubrication cycle.
(WET AND HUMID APPLICATIONS)							
CHEMICAL	Mission Pumps	Bearings (Outboard)	Climatic Ambient	Continuous and intermittent. Outside installations exposed to weather.	Lithium Base Mulit-Purpose	Satisfactory on 3 month lubrication cycle. To tie-in lubrication with other routine maintenance desired to extend cycle to 6 months. However beyond 4 months frequent bearing failure occurred.	Lubrication cycle extended to 6 months with ample margin of safety.
CHEMICAL	Centrifugal Pumps	Bearings (Inboard)	Climatic Ambient to 180°	Continuous and intermittent. Pumping water.	Lithium Base Multi-Purpose	Some pump bearings provided with grease nipples for lubrication while in service; others hand packed with grease at time of assembly. Various lubrication schedules depending on type of service etc.	On the average lubrication periods extended by a factor of 2 and bearing failures reduced.
METAL WORKING	Machine Tools	Slides, ways, worms, chucks, bearings	Shop Ambient	Washing action of water base cutting solution displaces grease.	Lithium Base Multi-Purpose	Satisfactory on 2-shift lubrication cycle.	Lubrication cycle extended to 4 shifts.
TEXTILE	Ager	Roll Support Bearings (Outboard)	200/212	Continuous. Contamination with steam/condensate containing various chemicals, acids or alkalies according to process.	Lithium Base Multi-Purpose	Satisfactory on weekly lubrication cycle.	Lubrication cycle extended to 3 weeks.
AUTOMOTIVE	Pallets (Auto-Body Assembly and Finishing)	Castor Swivel and Wheel Bearings	180/200 270/290	Series of operations includes: Detergent wash. "Bonderite" wash. Baking of prime and finishing coats.	High Melting Point Calcium Base	Due to excessive wash-out grease applied every 2 days.	Lubrication cycle extended to 4 days.
CHEMICAL	Rotary Steam Joints	Bearings	220/360	Continuous and intermittent; various sizes and speeds.	Clay Base	Satisfactory on 7 to 30 day lubrication cycle depending on application.	Equally satisfactory on same lubrication cycle and more economical.
TEXTILE	Hot Tenter	Adjusting screws and gears.	340	Continuous High humidity.	Lithium Base Multi-Purpose Clay Base	Satisfactory on 3 week relubrication cycle. Satisfactory on 4 week relubrication cycle.	Satisfactory on 6 week relubrication cycle.
PRECAST CONCRETE BLOCKS	Autoclave Cars	Wheel Bearings	350 (145 pounds steam)	Intermittent. Curing period 12 hours.	Silicone ($6.00 pound)	On a twice weekly lubrication cycle wheels frequently "froze" necessitating removal in some instances to clean and relubricate bearings.	On a 2 day lubrication cycle "frozen" wheels and cleaning of bearings eliminated.

**Antifriction Bearings except where indicated.*

shown in Table II.

These data and other laboratory evaluation studies indicated that this new inorganic microgel grease had the inherent properties requisite to an improved multipurpose type industrial grease. A series of field evaluation tests confirmed this premise and the grease was made available commercially during the latter part of 1955.

PERFORMANCE IN INDUSTRIAL APPLICATIONS

Typical case histories are presented in Table I to illustrate the performance level of this new multipurpose grease in a variety of applications covering a wide range of operating conditions. Persual will show that significant progress has been made in upgrading simultaneously those functional characteristics which, individually and collectively can restrict continuing implementation of the multipurpose grease concept; i. e., the temperature ceiling and effective service life under both dry and wet operating conditions. It is equally important to note that this has been accomplished without sacrificing other characteristics required of the multipurpose type grease, such as good pumpability, adequate low temperature properties, and ability to protect bearing surfaces from corrosion, particularly during shutdown periods.

But have these functional improvements been accomplished economically? Is it practicable to use such a grease for all grease applications in the majority of industrial plants, or does the unit cost tend to restrict its use to the more severe and troublesome applications?

At the present time, the unit cost of this new microgel grease is 10% to 15% above that of the lithium base multipurpose grease referred to earlier. Increasing consumer acceptance is evidence that this small differential in unit cost is insignificant when compared with the economies resulting from improved performance.

Consumer reaction to date has followed a fairly consistent pattern. Usually, the microgel grease is tried initially in an application which for one reason or another presents a lubrication or maintenance problem. In most instances, the resulting benefits have encouraged the consumer to initiate a progressive and expanding evaluation of the product in other less stringent applications. For example, fully integrated textile finishing plants employ a multiplicity of processes that, insofar as grease applications are concerned, involve operating conditions ranging from mild to severe. Several such companies, some previously using a lithium base multipurpose grease, the others a number of greases specially selected for particular types of operation, have progressively extended the use of this new microgel grease to all grease applications throughout their respective plants. Similarly, in other industries.

	MULTIPURPOSE LITHIUM BASE GREASE	MULTIPURPOSE INORGANIC MICROGEL GREASE
Dropping Point	———	Superior
Oxidation Stability (Static)	Similar	
Mechanical Stability Characteristics	———	Superior
Pumpability Characteristics	Similar	
Low Temperature Torque Characteristics	Similar	
Water Stability Characteristics	———	Superior
Corrosion Protection Characteristics	Similar	
Metal Corrosion Characteristics	Similar	
Oil Separation Characteristics	———	Superior
Bearing Performance Characteristics	———	Superior
Wear Characteristics	Similar	

Table II. A qualitative comparison chart

As a case in point, a manufacturer of major domestic appliances was using a special high temperature grease on the porcelain enamel finish conveyor line and a lithium base multipurpose grease for all other grease applications, such as various conveyors, shears, presses, blowers, pumps, equipment for extruding plastics, etc. The latter grease was considered very satisfactory except on the baked enamel finish line where grease contamination of some parts occurred during the drying stage following bonderizing and washing. Today, this plant is using the new microgel grease for all grease applications including the porcelain enamel line. In another metal working plant three greases were used: one for heat treat ovens and cleaning equipment, one for electric motors and the other for general plant lubrication, including machine tools. This plant also adopted the microgel grease for all grease applications.

Laboratory and field evaluation studies show that an appropriately formulated and processed inorganic microgel grease can equal and, in most cases surpass, lithium base industrial multipurpose greases in all significant properties. The inorganic microgel grease is superior with respect to temperature ceiling and effective service life under both dry and wet operating conditions. These functional improvements have been accomplished without materially increasing lubricant unit cost. Thus, the versatility and scope of the industrial multi-purpose grease is considerably broadened. It is anticipated that the inorganic microgel type of multipurpose grease will play an increasingly important role in industrial lubrication.

APPENDIX

Torque Rate Ratio

Conrad 204K bearing packed with 6.5 gms grease and rotated 100 revolutions at 200 rpm to distribute grease. Bearing assembly cooled to indicated temperatures and average torque determined over 2 revolutions when bearing is rotated at 2 rpm. Torque is measured in inch-lbs and adjustem for rate of turning. Since 2 rpm $= 4\pi/60$ radians per second, dividing the torque by this factor gives torque rate ratio in inch-lbs seconds per radian.

Shell Glass Jar Corrosion Test

Timken bearing (cup No. 1520, cone No. 15118) is packed with grease and rotated at 1750 rpm for one minute under an axial load of 40 lbs. to distribute the grease. The bearing is placed in an 8 oz. cosmetic jar, 12 ml. of distilled water containing 0.05% wt. sodium chloride poured over it, the jar sealed and stored at room temperature for the desired test

period. The extent of corrosion is rated from 0 to 10 in which 0 denotes high corrosion and 10 no corrosion.

Commentary

S. R. Calish,
California Research Corp.

The author is to be congratulated on a clearly written paper which outlines the place for an inorganic thickened grease in the line of products offered to industry.

Very few criticisms of the author's claims or conclusions can be offered, for his paper is a documentary of service experience. In making a comparison between a lithium base grease and the inorganic microgel grease, somewhat more specific information about the exact lithium soap base employed would have been helpful. Not all lithium base greases would be as good as that selected by the author (it is assumed that a lithium 12-hydroxy-stearate was used), while some may even be better.

The most significant omission from the list of applications in which the inorganic grease performed creditably is in electric motors. The paper contains not a single mention of service experience with the inorganic microgel grease in motor bearings. It seems unlikely that the long list of successful applications could have been obtained without some experience in motors, good or bad. If it is satisfactory, this most important aspect should have been included. If unsatisfactory, a word of caution to that effect would have lent credence to the other claims.

The interpretation of test results and the basic requirements for products are the large remaining differences among lubricant suppliers. The great variety in new grease bases appearing on the commercial market today is due to these basic differences in interpretation and requirements.

Author's Closure

In Table III, the lithium base grease in question is identified as a 12-hydroxy stearate type. As assumed by Mr. Calish, the lithium base greases referred to in Table I, and text of the paper, are of this type also.

Use of the inorganic microgel grease for the lubrication of electric motor bearings is mentioned or inferred in the section dealing with companies which have successfully adopted this product for all grease applications throughout their plants.

TABLE III

	LITHIUM BASE GREASE	INORGANIC MICROGEL GREASE
TYPE THICKENER	Lithium 12-Hydroxy Stearate	Clay Microgel
DROPPING POINT, °F. (ASTM D566-42)	358	None
OXIDATION STABILITY		
Oxygen Bomb Test (ASTM D942-50)		
Pressure Drop, psi @ 100 hours	5	5
Induction Period, hours	> 1000	> 1000
MECHANICAL STABILITY CHARACTERISTICS		
Penetration @ 77°F. (ASTM D217-52T)		
Unworked	277	273
Worked 60 strokes	266	293
Worked 1,000 strokes	268	301
Worked 10,000 strokes	278	307
Worked 100,000 strokes	302	325
Shell Micro-Penetration @ 77°F. (SMS 479/48G)		
Unworked	111	98
Shell Rolling Stability (SMS 466/47G)		
Hours to 230 micro-penetration @ 77°F.		
when rolled at: 77°F.	350	1000
212°F.	90	350
PUMPABILITY CHARACTERISTICS		
Apparent Viscosity (ASTM D1092-55)		
At 0°F. and shear rate 25 sec. $^{-1}$, poises	2650	3250
At 0°F. and shear rate 100 sec. $^{-1}$, poises	1200	1630
At 0°F. and shear rate 200 sec. $^{-1}$, poises	1120	1070
At 0°F. and shear rate 500 sec. $^{-1}$, poises	590	760
At 0°F. and shear rate 1000 sec. $^{-1}$, poises	460	550
At 32°F. and shear rate 25 sec. $^{-1}$, poises	780	820
At 32°F. and shear rate 100 sec. $^{-1}$, poises	320	380
At 32°F. and shear rate 500 sec. $^{-1}$, poises	138	185
At 32°F. and shear rate 1000 sec. $^{-1}$, poises	102	140
At 77°F. and shear rate 25 sec. $^{-1}$, poises	510	460
At 77°F. and shear rate 100 sec. $^{-1}$, poises	160	162
At 77°F. and shear rate 500 sec. $^{-1}$, poises	49	59
At 77°F. and shear rate 1000 sec. $^{-1}$, poises	31	40
LOW TEMPERATURE TORQUE CHARACTERISTICS		
Torque Rate Ratio (*)		
At 10°F., inch-lbs. sec./radian	0.5	0.9
At 0°F., inch-lbs. sec./radian	0.7	1.3
At -10°F., inch-lbs. sec./radian	0.9	2.1
At -20°F., inch-lbs. sec./radian	1.9	3.8
At -32°F., inch-lbs. sec./radian	6.3	8.3
At -40°F., inch-lbs. sec./radian	> 10	> 10
WATER STABILITY CHARACTERISTICS		
Water Washout (ASTM D1264-53T)		
Loss @ 100°F., % wt.	1.5	2
Loss @ 175°F., % wt.	33	25
Wheel Bearing Test (modified ASTM D1263-53T)		
6 hours @ 180°F. with 20% wt. water mixed in grease.		
Leakage, % wt.	< 1	< 1
Over-all rating	Pass	Pass
Water Absorption Test (AN-G-3a)		
Water absorbed when saturated, % wt.	50	72
Micro-penetration @ 77°F. saturated grease	148	95
CORROSION PROTECTION CHARACTERISTICS		
Shell Glass Jar Corrosion Test (*)		
Rating @ 120 hrs.	10	10
METAL CORROSION CHARACTERISTICS		
Metal strip in grease 50 hours @ 160°F.	Unchanged	Unchanged
Steel, original grease	Unchanged	Unchanged
Copper, original grease	Unchanged	Unchanged
Steel, grease + 10% water	Very slight	Very slight
Copper, grease + 10% water	stain on strip; grease unchanged	stain on strip; grease unchanged
OIL SEPARATION CHARACTERISTICS		
Oil Separation on Storage (I. P. 121/48)		
7 days @ 77°F., oil separation % wt.	3.0	0.1
Separation of Oil from Grease (VV-L-791e (Method 321.1)		
50 hours @ 212°F., oil separation, % wt.	3.8	1.3
2 hours @ 300°F., oil separation, % wt.	7.0	2.0
Shell Filtration Stability of Grease (SMS 483/50G)		
5 hours @ 730 mm. pressure, room temperature, oil separation, % wt.	15.0	38
BEARING PERFORMANCE CHARACTERISTICS		
Wheel Bearing Test, (modified ASTM D1263-53T)		
6 hours @ 275°F: Leakage, % wt.	4.5	1
Over-all rating	Pass	Pass
Rig Test with 206K Bearing, 3600 r.p.m., 300°F.		
Load: 200 lbs. radial and 80 lbs. axial		
Cycle: 20 hours on test and 4 hours down—cooled to room temp.		
Evidence of failure:		
Rapid temperature rise or excessive bearing friction		
Cycles to failure	10	25
Rig Test with 206 KDD (double shielded) bearing		
Load: 80 lbs. axial		
Other test conditions as above.		
Cycles to failure	5	19
WEAR CHARACTERISTICS		
Shell Wear Test		
Timken Bearing (Cup 15250, Cone 15118) 1750 RPM, 540 lbs. load, ambient temp., 55 hours.		
Total iron pickup in grease, mgs.		
1st bearing	2.5	1.9
2nd bearing	2.3	2.3

(*) *Test procedure outlined in Appendix*

Choose Your Press Drawing Lubricants With Care

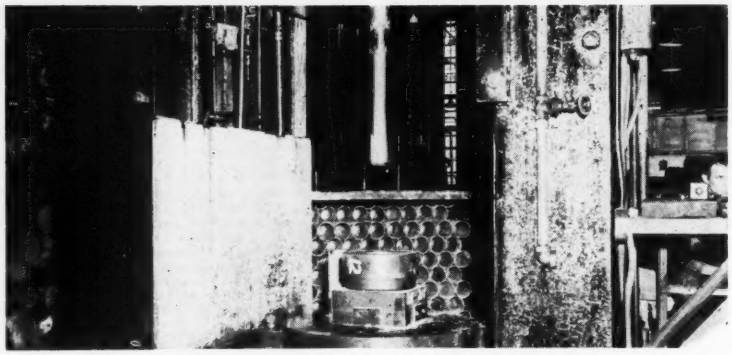
by Leon Salz, Manager, Lubricants Division, Magnus Chemical Co.

SAVINGS in labor, materials, utilities, and overhead costs . . . a metalworking plant, now more than ever before, must be alertly cost-conscious of these factors. With a highly competitive market now existing among stamping and deep-drawing plants and wages and prices at an all-time high, overall production costs must be pared carefully.

At present, contracts and sales may be lost on small differentials, arising from miscalculation of the difficulties that can arise in a drawing operation. Not uncommon is the shop that submits a bid on the basis of experimental trial runs, only to find that serious problems arise in mass production.

Inadequate lubrication is one of the most frequent causes of difficulty in press drawing. Selection of a suitable drawing lubricant will often overcome problems arising from design of punch and die, metal quality, and severity of draw. Excessive rejects attributable to poor steel ductility when using soluble oil as a lubricant can often be corrected by changing to a compounded drawing oil. A difficult stainless steel draw may be possible with only one type of lubricant composition out of many possible choices.

Unfortunately, press room personnel generally make their selection of lubricants on a "trial and error" basis. Lubricants are frequently known to their users only by trade designations, and little use is made of available technical information, limited though it may be. This article is primarily devoted to removing some of the "mystery" surrounding the subject of press drawing lubrication. A background of practical information, will, it is hoped, be useful in understanding and overcoming pertinent problems.



1. Hydraulic drawing press showing punch and die used in the manufacture of gas cylinders.

FUNCTIONS OF DRAWING LUBRICANTS

The purpose of a metal drawing lubricant is to provide a film between the work and the tools (punch and die), capable of permitting the desired shaping of metal under pressure with a minimum of friction and wear.

When work-tool pressures are low, straight mineral oil, general purpose soluble oil, or dilute soap solutions can give satisfactory service because the force is not great enough to rupture the lubricating film. As pressures become greater, compounds containing sufficient oiliness (polar) materials such as fatty oils, waxes and concentrated soaps are required. These physically adherent materials are adsorbed to metal surfaces, maintaining a persistent mono-molecular film where lubricants lacking sufficient oiliness would be squeezed out. When pressures are very high, as in severe draws, the corresponding rise in work-tool temperatures reduces the adherency of oiliness materials. Some form of "extreme pressure" material is then usually required if welding or seizure between the tool and work surfaces are to be avoided. (Welding or seizure is evidenced by metal build-up on the punch or die, causing scratch marks on the work drawn. Improper lubrication may also result in tearing of metal, wrinkling, buckling and other reject conditions).

The extreme pressure agents available function by either chemical or mechanical methods. Those that provide EP characteristics to drawing lubricants by a chemical method usually contain loosely combined chlorine or sulfur which react with the punch, die, and work to form chemically protective films that are highly resistant to welding. Compounds that function mechanically minimize friction by incorporation of powdered spacing agents (pigments) such as chalk or graphite, these substances acting as mechanical separators between the tools and the work.

The highly technical phenomena involved in understanding the function of press drawing compounds may be summarized as follows: Drawing compounds require increasing amounts of metal adherent "oiliness" materials as work-tool pressure becomes greater. Supplementation or replacement by EP materials is frequently necessary in severe drawing operations.

2. Drawing press in operation. The punch moves downward while the die remains stationary. In the process, the work is elongated to the desired shape.

HOW DIFFICULT IS YOUR DRAWING JOB?

There are some shape drawing jobs where press operators report that any lubricant will do the work satisfactorily. There are other jobs where every lubricant fails. In still other instances, a job set up from the same blueprint in two shops using the identical lubricant will give no trouble in one plant and cause no end of headaches and down-time to the other. Obviously, there must be a number of factors independent of the lubricant which exert a profound effect upon the ease or difficulty that will be encountered in the drawing operation. These factors may be classified with respect to (1) Type of Metal (2) Condition of Metal (3) Severity of Draw and (4) Efficiency of Die.

Type of Metal

Metallic materials vary considerably in their drawability. Metals with high yield strengths require greater forces for plastic deformation than those of lesser strengths. The higher forces are associated with greater pressures which the lubricant must withstand. Among the more common metals, stainless steel gives the most trouble, followed in order of decreasing difficulty by high carbon steel, low carbon steel, brass and aluminum.

Condition of Metal

The processing of metal in the course of manufacture has an important influence on its drawability. In attempting to attain optimum metallographic structures for certain end uses, the metal may be subjected to one or more heat treating processes, including annealing, normalizing, spherodizing, patenting, etc. The arrangement of such treatments materially affects the forces required for metal deformation.

A highly ductile and tenacious metal is most desirable. Ductility is related primarily to the crystal (or grain) size of the metallic structure. For a given metal, greater ductility and correspondingly superior drawability are associated with a larger average grain size. The purpose of intermittent annealing after drawing is to increase the grain size and, thereby, enhance drawability.

A poor surface condition of the metal can greatly increase the force required for deformation. Excessive amounts of abrasive oxides should be avoided and, the surface should be free of dirt, scale or hydrogen embrittlement. Optimum results may be expected from physically and near-chemically clean surfaces which are slightly rough for better retention of the lubricant.

Severity of Draw

Drawing operations vary in degree of severity from mild metal deformation, as in light stampings, to the extreme pressures involved in deep drawing of heavy gauge gas cylinders. Between these extremes are drawing operations involving the manufacture of such diverse-shaped hollowed objects as voltage boxes, pencil caps, pots and pans, gas range tops, refrigerator doors and oil filter cups.

Deep draws, heavy metal gauges and sharp angles require greater drawing pressures and more effective lubricants than corresponding shallow draws, thin metal gauges and smooth curvatures.

Efficiency of Die

One of the most critical factors, often overlooked, in determining the difficulty of a drawing operation is the efficiency of the punch and die. These tools must be properly constructed with sufficient clearance, correct angles and in accordance with the limitations of the metal being drawn if rejects are to be kept at a minimum.

3. Dismantled punch and die used in the manufacture of gas cylinders.

It is not uncommon to find that tools constructed with sharp corners will cause excessive localized high drawing pressures, requiring the need for heavily compounded draw-

ing oils. Correction of the die defect would allow the job to be run with fewer rejects and a less costly lubricant.

The materials of construction in the manufacture of the tools are also of prime importance. Harder tools tend to weld less than softer tools. Tungsten carbide or chromium plated materials, for example, will resist metallic build-up for a longer period of time than high carbon steels. Mirror finishes on tools produced by diamond lapping, extends their period of service appreciably.

INDUSTRIAL REQUIREMENTS FOR PRESS DRAWING LUBRICANTS

1. **Satisfactory Performance —** The drawing lubricant must be capable of doing the job with a reasonable degree of efficiency. This requires that the product chosen have adequate oiliness and/or EP characteristics to withstand the pressure of metal deformation. The drawing lubricant which gives the best performance is the one which permits the desired draw with a minimum of rejects and metallic tool build-up.
2. **Physiologically Safe —** Lubricants containing white lead, carbon tetrachloride or other toxic material should not be used. The product's components should be free from chemicals that have been established as skin irritants, such as chromates. The use of conventional sulfurized and chlorinated additives, often blamed for dermatological difficulties, are generally not the direct cause, although some individuals are allergic to these materials. The more common cause of dermatitis is bacteria found under unhygienic conditions that are carried to the skin by the drawing lubricant. The addition of germicides to drawing compounds, especially the water dispersible types, has proved helpful in minimizing these problems.
3. **Non-Corrosiveness —** Rusting is the most common of the various forms of corrosion attributable to the effects of drawing compounds on metal surfaces. Rusting is most frequently encountered with water dispersible compounds and may be minimized or eliminated by either (a) increasing the ratio of product to water, (b) adding a rust inhibitor to the product or water dispersion or (c) cleaning the parts after drawing and applying a rust protective coating to the part itself.

   Greenish or bluish stains noted on the surface of copper and copper alloys (brass and bronze) are attributable to copper soap formation by reaction of the metal with free fatty acids present in the lubricant. This condition can be virtually eliminated by using a product with a free fatty acid content of one percent maximum.

   White stains on aluminum, zinc and alloys of these metals are attributable to salts formed by reaction of the metal with alkalinity present in most water dispersible products. This problem may be expected if the pH is above 9. The use of water insoluble drawing oils is suggested as a simple solution to this problem.
4. **Stability of Product —** Inasmuch as products are frequently not used for several months after manufacture, they must possess storage stability. Products must be stable in the complete temperature range from the hottest summer day to the freezing conditions of winter. Liquid products should not gel or separate components, nor should solid products "bleed" oil or form hard surface crusts.

   Where fats are used, an inhibitor may be needed to prevent rancidity. Pigmented soap-fat pastes, containing suspended spacing agents, must have sufficient body so as not to separate the dispersed solid.
5. **Ease of Application —** A product that requires mixing with a diluent, such as water or mineral oil, should disperse easily and without special equipment. One of the more convenient methods of applying the lubricant is by continuous circulation to the work. Lubricants suitable for this procedure should be nonfoaming. Other satisfactory means of application include brushing the lubricant on the work, passing the work through rollers coated with the lubricant, dipping the "blanks" into the drawing compound, lubricant spray techniques and drip systems.
6. **Ease of Removal —** The removal of lubricants from drawn parts is generally carried out by means of either aqueous cleaning compounds or solvent degreasing. The former processes are most suitable for the removal of water dispersible drawing lubricants, whereas the effects of solvents are more adaptable to oil soluble products.

   It is unfortunate that some plants limit their selection of drawing lubricants to those most easily cleaned, or to the type of cleaning equipment readily available. Placing the cart before the horse may create inefficient operation when a superior lubricant could have reduced excessive rejects and down-time. The over-all economics of the complete process should be the prime consideration.
7. **Weldability —** In some cases it is desirable to conduct welding operations on drawn parts before cleaning. The use of certain water-dispersible compounds are most suitable under these conditions.
8. **Economy —** The total expense of the metal working operation from start to finish should be the only economic consideration. Included among these expenses should be labor cost of production plus labor cost for reconditioning punches and dies, tool life, cost of metal plus cost of rejects, overhead expense of presses, costs of cleaners and labor attendant to the cleaning process, etc.

   The price of the metal drawing lubricant is one of the smallest and least important of all production costs. Selection of the lubricant that materially reduces over-all production costs can be more than justified.

DRAWING LUBRICANT COMPONENTS

There are five principal classes of materials that may be present in press drawing compounds—oiliness agents, extreme pressure agents, emulsifiers, diluents and inhibitors. From this category of substances, the manufacturer selects appropriate individual compounds or mixtures of compounds and blends them.

Let us consider each of these five

classes separately, indicating characteristics that are common to all substances in a class and the variations within the group.

Oiliness Agents—These substances are organic compounds having a minimum of 14 carbon atoms and possessing one or more polar groups. The latter groups are characterized by a fixed combination of atoms that have strong physical adherency for metal surfaces and orient themselves tenaciously thereon. Typical of polar groups are the carboxyl group (—COOH) present in fatty acids, the carbonyl group (C=O) present in fats, and the hydroxyl (—OH) present in alcohols. The long carbon chain does not have an affinity for metal and stands out upright from the surface.

As a consequence of the orientation of polar groups to metal surfaces, the tool and work surfaces are separated by a distance equal to two lengths of carbon chains. This reduces the tendency toward welding and, in addition, provides slippage as the metal surfaces slide over the mono-molecular film. "Boundary Lubrication" is the term used to describe this condition, where the pressure encountered may be as high as 100,000 psi. This is in contrast to "Hydrodynamic" or thick film lubrication, as in the lubrication of bearings where pressures may be in the order of only a few hundred psi.

The most common oiliness agents are indicated below:

Fatty Acids — These materials are derived from fatty oils and fats and are usually long straight chain molecules containing a carboxyl polar group at one end, as illustrated. Examples of these substances are stearic acid, oleic acid and palmitic acid.

Fatty Oils and Fats — These materials are "glycerides" consisting of chemically combined glycerine and fatty acids. The distinction between fatty oils and fats is that the former are liquid at 68°F whereas the latter are solid. Fatty oils and fats typically possess three long chain carbon groups and associated polar groups, as illustrated. Examples of these substances are tallow, lard oil, castor oil and Neatsfoot oil.

Soaps — In its basic conception, a soap is the reaction product of an alkali and a fatty acid. Soaps possess a long carbon chain with a polar and metallic group at one end, such as the sodium soap illustrated. Examples of these substances are sodium stearate, potassium stearate, sodium oleate, etc.

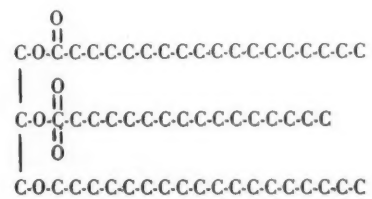
Waxes — The wax materials used as oiliness agents are "esters" of plant or animal origin, found in nature as chemically combined fatty acids and high molecular weight alcohols, plus an appreciable quantity of uncombined reactants. The structural outline of a typical wax is illustrated.

Examples are beeswax and Carnauba wax.

Synthetics — Although the natural fatty materials of plant

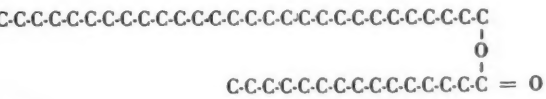
Structural Outline of Typical Fatty Acid

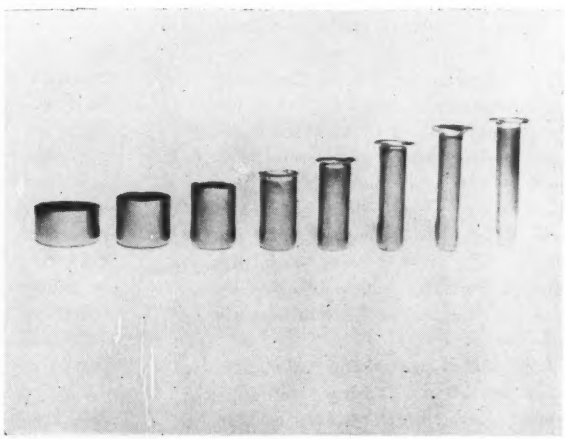
Structural Outline of Typical Fatty Oil or Fat



Structural Outline of Typical Sodium (Na) Soap

Structural Outline of Typical Wax





4. (left) Variety of drawn parts — Voltage regulator box, cage for front wheel bearing, safety shoe cap, can cover stapler part. The term "stampings" is applied to parts that require mild metal deformation in the punch press. "Deep Drawings" require severe metal deformation.

5. (right) Shows successive stages in the manufacture of a deeply drawn part such as a pen cap. Each stage requires a separate punch and die.

and animal origin are most widely used as oiliness agents, a variety of modifications have been synthesized. The more promising of the synthetic group for metal drawing are the partially esterfied glycerides. These materials, like the natural compounds used for oiliness purposes, have the usual combination of a long carbon chain and a polar group.

Extreme Pressure Agents (EP) — In the more severe drawing operations, where pressures and temperatures are exceedingly high, oiliness materials become disoriented. Under those conditions, extreme pressure agents are required in the drawing lubricant to prevent welding of sliding surfaces.

An EP lubricant is any material that tends to prevent moving metal surfaces from welding under conditions of high temperature and pressure. Such materials may perform this function by either chemical or mechanical methods. The chemical types of EP agents release a substance that reacts with the metal surface to form a metallic film that is more resistant to welding than the original metal. Chlorinated and sulfurized compounds are the most widely used EP agents of this type, forming welding-resistant chloride or sulfide compounds respectively on the metal surfaces. The mechanical types of EP agents are chemically inactive but perform their weld-resisting function by physically separating the moving metals. The most widely used of these pigments are chalk, mica, graphite and zinc oxide.

The use of chlorinated compounds as chemical type EP agents is rapidly displacing the use of the better known sulfurized products. Newer developments among chlorinated compounds have been found more efficient as anti-weld materials for metal drawing. Their light color and lack of foul odor appeal to the operator. Chlorinated compounds that combine oiliness characteristics in addition to excellent EP qualities are now available.

Chlorinated compounds are especially useful on stainless and alloy steels. Care must be exercised in their use on carbon steels because of the possibility of partial decomposition to hydrochloric acid and resultant corrosion. Their use on copper alloys may be limited due to surface staining, attributable to the formation of greenish-blue colored copper chloride. Sulphur may be present in any of the following forms:

6. Lubrication on the "blanks" may be by brush, as shown, lubricant drip procedures, passing through immersed rollers or circulating systems.

1. **Pure Sulfur** — This is a yellow powder known as "flowers of sulfur". In this chemically uncombined state, sulfur is highly reactive, usually being excessive for most metalworking operations.
2. **Sulfurized Mineral Oil** — This is prepared by chemically reacting pure sulfur and mineral oil at an elevated temperature. The maximum amount of sulfur that can be combined in this manner is approximately 1½%. These oils are light colored and transparent.
3. **Sulfurized Fatty Oils and Fats** — These materials are prepared by chemical reaction between pure sulfur and fatty oils or fats at an elevated temperature. Such compounds may be prepared in corrosive or non-corrosive form. The corrosive form contains about 16% sulfur, whereas the non-corrosive form contains about 12%. Sulfurized fatty oils and fats are dark brown in color and are the most widely used sulfur containing EP additives for drawing compounds.
4. **Other sulfurized compounds** — These are prepared by a chemical reaction of pure sulfur with fat derivatives, terpenes, etc. This miscellaneous group covers sulfur compounds prepared as improvements over conventional materials with respect to efficiency or as low cost substitutes for sulfurized fats.

The EP characteristics of sulfur compounds vary considerably. Effectiveness of the sulfur compound is dependent upon its activity. An active sulfur compound is one which readily releases sulfur under conditions of high temperatures and pressure to form a metallic sulfide on the punch, die, and work, providing resistance to welding. Drawing compounds containing active sulfur are termed "corrosive" because the sulfur is sufficiently active to discolor, or form a black stain (copper sulfide) on copper, brass or bronze.

Compounds containing active or corrosive sulfur are more efficient than those containing inactive sulfur. The latter are termed "non-corrosive" because the sulfur will not attack copper, brass or bronze. Accordingly, the corrosive type is employed in drawing ferrous metals and is not suitable for copper alloys.

Among the EP type spacing agents commonly used are the following: chalk, borax, lithopone, zinc oxide, white lead, talc, graphite and mica. The last three named are unctuous and possess lubricating ability of

their own. They have been termed "solid lubricants" and cause less lubricating friction but do not pulverize upon being subjected to high pressure, as do the other materials. They are therefore probably not as efficient as mechanical separators of sliding surfaces.

Emulsifiers — In the manufacture of water dispersible drawing compounds, emulsifiers must be added to solubilize water insoluble components in aqueous media.

Soaps are the most widely used emulsifiers. The two principal varieties of soaps employed are sodium soaps and potassium soaps. The latter type gives softer products that are more easily dissolved than the former and are therefore usually preferred for liquid and paste compositions. The sodium soaps are preferred where hard films are desired, as in dry film products.

Soaps made from inorganic alkalies leave a residue after heat decomposition or burning. Where a soap is desired that will burn off completely in an annealing furnace, an organic alkali such as triethanolamine may be used for saponification with fatty acid.

Soluble oils usually use a combination of soaps and mineral oil sulfonates as emulsifiers. This is done to give these products a proper balance of properties providing for rapid dispersion in water, rust protection and hard water resistance.

Diluents — A diluent is a low cost material which acts as a carrier or extender for the more costly and essential components of drawing lubricant composition. Water, mineral oil and petroleum solvents are the diluents most commonly used.

In addition to their important function of diluting the drawing lubricant composition, diluents help dissipate the heat formed during metalworking. Where circulating systems are in service, the dissipation of heat may be a more important contribution of the diluent to good lubrication than its service as a cost reducer. Water, in this respect, is the best coolant generally available; about twice as effective as petroleum oils.

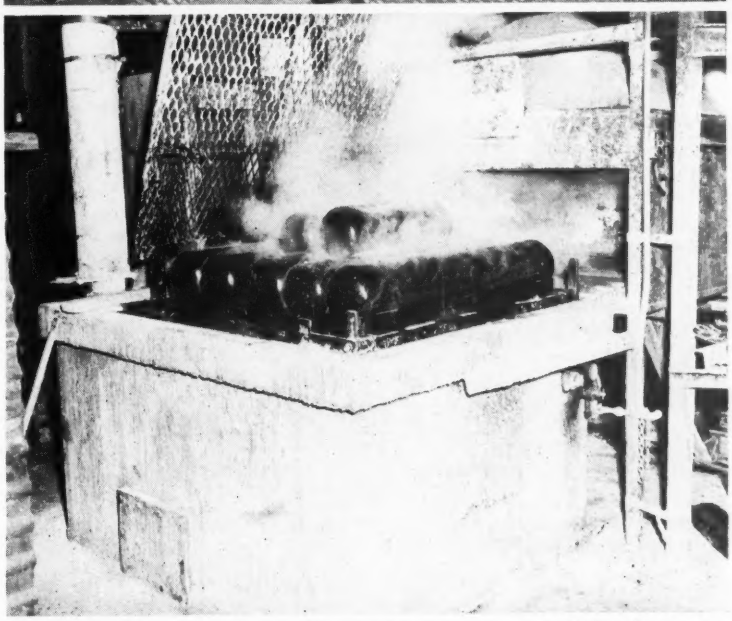
Inhibitors — These are small amounts of complex chemicals added to a drawing lubricant composition for the purpose of eliminating or minimizing some undesirable property. Inhibitors are available for retarding rust formation, foam, bacteriological decomposition, oxidation, etc. Their need is determined by the product.

CLASSIFICATION OF PRESS DRAWING LUBRICANTS

Now that we have described the components of press drawing lubricants and their functions, it is believed that a tabulation of finished products in terms of typical combinations of principal raw material will be better understandable. The compositions are classified as either water dispersible or oil soluble, and their uses are indicated in the accompanying recommendation chart.

A brief description of each type of product follows:

Soluble Oil — The conventional general-purpose soluble oil is characterized by the formation of a milky, opaque emulsion when the oil is added to water. Oils of this type are prepared by adding emulsifiers to straight mineral oil. Heavy duty soluble oils, which have EP qualities, have sulfurized or chlorinated compounds added for this purpose. Soluble oils are



7. (top) A blank placed in the drawing press. 8. Partially drawn gas cylinders being coated with a "dry film" lubricant by immersion in a hot aqueous solution.

mixed with water in the ratio of 1:5 to 1:20.

Soap Solution — These are concentrated solutions of potassium or sodium soap in water. Such products have the advantages of rapid solubility in water and may be compounded so that they are "self-cleaners" in addition to being lubricants. They provide excellent "slip" and wet metal surfaces uniformly to form an unbroken film. Because of their foaming characteristics, they are not recommended for use in circulating systems.

Non-Pigmented Soap-Fat Compound — These products are pastes having the appearance of mayonnaise. They consist of approximately 35-60% fat with the remainder being soap and water. The performance of these products is highly rated, and they are among the most popular for moderately severe drawing where a water dispersible product is desired. Usual ratios of product to water are 1:1 to 1:5.

Pigmented Soap-Fat Compound — Such compositions are formulated for the more severe drawing operations requiring use of a water dispersible product. They contain pigment concentrations in the range of approximately 10-50%, the remainder being soap, fat and water. Difficult pigment removal from the drawn part in the subsequent cleaning operation is a serious shortcoming in the otherwise superior performance of these products.

"Dry Film" Soaps — These products are among the newer developments in press drawing lubrication. They consist principally of a sodium soap and a water soluble spacing agent, such as borax. Drawn parts to be coated by dry film soaps are immersed in a 10-25% solution of the product at 180-200°F for 3 minutes and then withdrawn for oven or air drying. The resultant film, which is thin, dry, and plastic gives much better lubrication than corresponding aqueous solutions. In addition to the fine drawing characteristics of dry film lubricants, there is less mess at press, drawn parts are easy to handle, and cleaning is comparatively easy for a heavy duty lubricant. Disadvantages include possible need for special dipping and drying equipment and adverse effect of high humidity on film. Dry film soaps are impractical and needless for drawing small parts. Their principal use is for large area draws such as refrigerator doors, bath tubs or gas cylinders.

Straight Mineral Oil — Inexpensive mineral oil of naphthenic origin having a viscosity of 100-300 Saybolt seconds at 100°F is entirely suitable. In metal drawing, there is no need for the advantages in chemical stability and minimum viscosity-temperature change offered by high quality paraffin or Pennsylvania grade oil.

Mineral Oil — Oiliness Blend — These compositions are mineral oil blends with 5 to 50% of oiliness materials, usually fatty oils.

Straight Fatty Oil — The use of lard oil is most popular because of its efficiency, comparatively low cost, availability, and liquid state.

Mineral Oil — Sulfurized Oil Blends — These compositions are blends of mineral oil with 5 to 50% of either corrosive or non-corrosive sulfurized compounds, usually sulfurized lard or sperm oil.

Mineral Oil — Chlorinated Oil Blend — These compositions are blends of mineral oil with 5 to 50% of chlorinated oil.

Straight Sulfurized Oil — Described under the heading of "Extreme Pressure Agents".

Straight Chlorinated Oil — Reaction products of chlorine gas with hydrocarbons, fats or waxes to form non-volatile, light colored syrupy liquids.

METAL COATINGS

A study of press drawing lubricants would not be complete without some mention of special chemical or metallic coatings sometimes applied to ferrous metals as an aid to the lubrication process.

The application of phosphate coatings on carbon steel that is to be deep drawn has been steadily gaining popularity. While this process is costly, its use is frequently justified in severe drawing operations. The coating is applied by dipping the cleaned metal in a hot phosphate solution. Inasmuch as phosphorous is a chemical type EP agent, anti-weld protection is enhanced in the drawing operation. In addition, the sponge-like coating produced on the metal as a result of phosphatizing helps hold the drawing lubricant on the metal surface. The use of Oxalate coatings is applied in like manner for stainless steels for similar purposes.

From time to time, soft ductile metals are deposited on alloy steels, especially stainless, prior to drawing for the purpose of reducing the severity of difficult operations. These metal coatings, which are either copper, lead, zinc, or tin, enhance the drawability of the base metal and are applied by electrolytic means, hot dipping or chemical displacement.

RECOMMENDATION CHART

	Carbon Steels	Alloy Steels	Stainless Steels	Aluminum	Copper Brass Bronze
Stamping					
Water Dispersible Lubricant	1, 2, 3	3	4	2	1, 2, 3
Oil Soluble Lubricant	6, 7, 10	10, 11	11	6, 7	6, 7, 9
Shallow Drawing					
Water Dispersible Lubricant	3,	4	—	—	2, 3
Oil Soluble Lubricant	7, 10, 11	13	11, 13	7, 8	7, 9
Deep Drawing					
Water Dispersible Lubricant	4, 5	4, 5	—	—	3, 4
Oil Soluble Lubricant	11	11	11, 13	8, 11	8, 11, 12

TYPES OF PRESS DRAWING LUBRICANTS

Water Dispersible

1. Soluble Oil
2. Soap Solution
3. Non-pigmented soap-fat compound
4. Pigmented soap-fat compound
5. "Dry Film" Soap

Oil Soluble

6. Straight Mineral Oil
7. Mineral Oil — Oiliness Blend
8. Straight Fatty Oil (or equivalent oiliness agent)
9. Mineral Oil — Sulfurized Oil Blend (non-corrosive type)
10. Mineral Oil — Sulfurized Oil Blend (corrosive type)
11. Mineral Oil — Chlorinated Oil Blend
12. Straight Sulfurized Oil (non-corrosive)
13. Straight Chlorinated Oil

Lube Lines

by A. F. Brewer*

Hardness, Surface Finish and Wear

There is a direct relationship between hardness of steel, frictional wear, surface finish, and lubrication. This holds true wherever steel-to-steel contact surfaces are in motion with respect to one another. Appreciation of this fact was a primary motive for metallurgical research in the field of heat treating, which is so important in producing today's steels of maximum strength, toughness and machinability.

Obviously, a machine built of moving parts which will be most resistant to wear and most conducive to effective lubrication is the most efficient machine.

Heat treating is not a latter day idea, it has been practiced for centuries — armorers for the Saracens, the Toledo blade, the equipment of the Crusaders are evidence of the skill which was built into armor by rule-of-thumb carburizing and quenching. They knew not why but they certainly did know how; and the fact that knights of old could whang each other's helmets with massive steel swords which usually outlasted their owners certainly spoke well for the forge-work of the contemporary armorers.

It was not until the machine age, however, that the relationship between hardness, strength and frictional wear required consideration. Even then, with little awareness of the value of lubrication, there was a period of stagnation until the hydrodynamic theory of lubrication less than a century ago. Since then friction between sliding or rolling surfaces has been taken most seriously. The laboratory research of Beauchamp Tower and Osborne Reynolds in the early 1880's formed an excellent foundation for subsequent study and our modern research procedures which today so forcibly relate lublication to low-cost maintenance and production.

The *Mechanism of Wear* is aptly discussed in "Wear of Metals" by D. Landau of the Nitralloy Corporation. He states that: "There are two principal ways in which wear occurs in metallic surfaces. The asperities of one of the surfaces either catch on the asperities of the other, or these asperities may penetrate into the hollows of the mating surface, and the particles of either, or both, of the surfaces are torn off when the surfaces slide away from each other. In the second method of wear the mating metals come into very close contact — molecular contact — owing to the high surface pressure, and a sort of incipient welding (galling) occurs. When such surfaces are separated they must be torn apart, with the particles of one adhering to the other, resulting in wear.

"Wear is usually a surface phenomenon, and occurs between parts which are in relative motion, both surfaces wearing at different rates if the materials are different. If both surfaces are of the same material, the rate of wear will depend on the relative cooling of each surface and even the form of the piece. Resistance to wear will depend on the hardness of the surfaces as well as the toughness of the core. The hardness prevents penetration while the toughness resists the tearing action."

HARDNESS AND HEAT

This brings us to the matter of heat treating as it relates to hardness. The basic procedure in heat treating involves quenching or rapid cooling of heated steel in order to develop a relatively harder surface structure—in other words, cooling from the surface inward. The rapidity of cooling or the rate at which heat flows from the interior of the piece towards the surface affects the subsequent hardness. This along with other characteristics can be controlled according to the size of the piece and the ultimate usage.

Wear-resisting steel surfaces are heat treated with a view to adaptability to surface finish or polishing. This treatment is required in the production of gears, cams, piston pins, cylinder liners, crankshafts, and ball or roller bearing elements. Good, though not always extremely high surface finish is necessary to enable the lubricant to exert the maximum of wettability (in accordance with its polarity) in order to assure that the lubricating film is giving good coverage and protection against chemical corrosion, rusting, and boundary lubrication. Research has indicated that the degree of surface finish obtained, either intentionally by honing, etc., or by "running-in" in service to "wear-in" the companion parts, seems to relate directly to the amount of load which can be carried safely. L. J. Collins of General Electric Company in "Developments in Gear Design and Their Lubrication Requirements" (Feb. 11, 1949) states: "If a tooth surface can be finished to a very high degree, load can be applied until the teeth break out. Under these conditions the oil film will not fail regardless of the viscosity of the oil. We have loaded several gears until the teeth broke out from fatigue and there was no indication of a lubrication failure. The surface stress was 250,000 psi and the oil viscosity was 40 SSU at 100°F."

The significance to Management is interesting. It is a question of economics: how much to pay for surface finish in the beginning, realizing that as soon as we have done with paying for "wear-in" we are commencing to pay for "wear-out". Relative hardness apparently is directly related to life expectancy of the piece and resistance to "wear-out". As hardness, in turn, relates to surface finish and rate of wear (in accordance with how effectually lubrication is maintained), the importance to Management is obvious.

*Consultant, and Author of *Basic Lubrication Practice.*

ALBERT SAUVEUR *was the first man in America to study steel through a microscope. In that way he noted the relative effects of temperature, amount of work, cooling rate and chemical composition on the grain size of both rolled and forged steels.*

From these studies, Dr. Sauveur was able to show that there was a certain critical temperature which, following hot work and slow cooling, yielded the smallest grain size. This brought immediate modifications in rolling and forging procedures which, until then, had been done at the highest possible heat.

Thus, in 1896, began researches into the working and heat treatment of steel which form the basis of our present knowledge of metallurgy. In almost every branch of this science, Albert Sauveur contributed useful and important knowledge. Harvard University describes him as "a founder of the science of metallography". For this, and his life's work as scientist, teacher and our first consulting metallurgist, his is a great name among steel makers.

Great Names in Steel Making #VI

The same day Albert Sauveur first focused his microscope on a specimen of steel, a mill employee on the Monongahela was busy paddling heavy grease on the roll necks of a small hand mill. The grease, a fatty base material having a high melting point, had recently been compounded by The Ironsides Company, of Columbus, Ohio. It was called "Shield" and performed so well that the name "Shield" in time, became synonymous with satisfactory lubricants.

The work of steel makers and lubrication engineers has come a long way since then — from small, slow mills, greased by hand with a paddle, to today's four and five stand continuous mills requiring automatically applied lubricants able to support sustained mill speeds of 4300 fpm and pressures as high as 25,000 psi.

In this progress, Ironsides specialists have "teamed" with mill superintendents, lubrication engineers and rollers to solve numerous problems. To achieve a satisfactory roller bearing Shield, for example, it was necessary to develop a pumpable, water repellent, extreme pressure lubricant that was also free-running in order to minimize the enormous power consumption of modern rolling mills. The even tougher problem of producing a domestic roll oil to replace imported palm oil was licked by the development of Palmoshield.

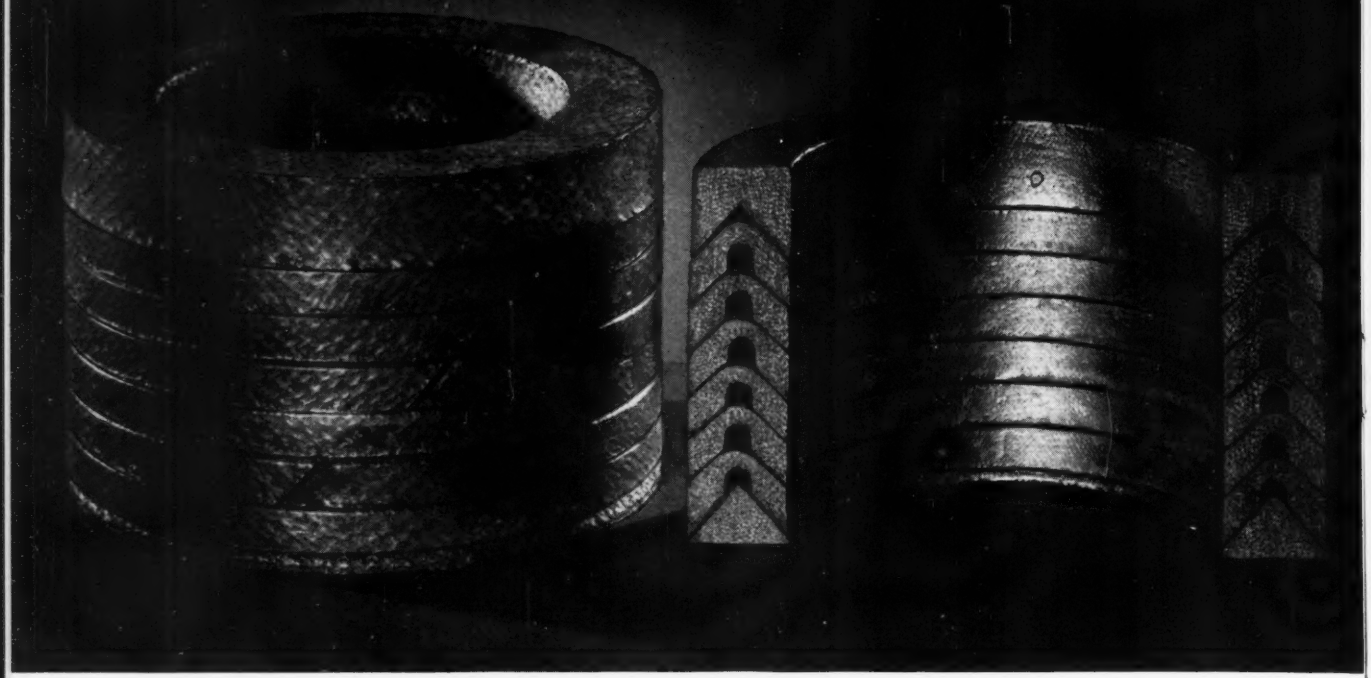
Ironsides engineers are equally accustomed to studying the problems of individual mills and compounding lubricants for specific conditions and preferences. These "custom tailored" lubricants are supplied in any quantity, from pails to tank cars.

Do you have such a problem—or an interest in improving present lubrication performance? A letter, or phone call, will bring one of our research engineers. The Ironsides Company, Columbus 16, Ohio.

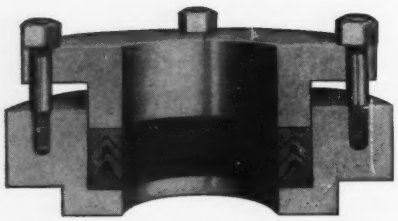
By the makers of Palmoshield
"the palm tree that grows in Ohio"

Jos. MARGULIES.

ONE OF THE GARLOCK 2,000



Why Garlock CHEVRON* Packing is really Automatic



This design is entirely different from ordinary V-type packings. CHEVRON has an exclusive hinge-like construction, assuring the automatic action for which it is designed. This also permits the use of less packing in shallower stuffing boxes.

The unique construction of Garlock CHEVRON permits free operation of rods or plungers at all pressures. As pressures increase the packing automatically tightens to prevent leakages. As pressures decline the CHEVRON Rings instantly ease off permitting free operation without leakage.

Therefore, after you make initial adjustment of the gland, no further adjustments are needed to compensate for variations in pressures.

Exclusive CHEVRON is one more part of "the famous Garlock 2,000" . . . two thousand different styles of packings, gaskets, and seals for every need—the only complete line. That is why you get *unbiased* recommendations from your Garlock representative. Call him today or write for CHEVRON Folder AD-115.

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Silicon Analyses of Diesel R. R. Crankcase Oils

Clay W. Lewis, Jr., Gustin-Bacon Mfg. Co., Kansas City, Mo.*

One of the principal causes of wear in cylinder assemblies of diesel engines in railroad locomotives is the air-borne abrasive in the intake air stream. Silica is a major component of most dust along railroad rights-of-way where track ballast and pulverized sand are present. Silicon analyses in samples of crankcase oil are usually regarded as a measure of these air-borne abrasives. There are several other possible ways silicon compounds may enter a diesel crankcase. Results must be carefully evaluated to avoid mistaken judgment which can cause unnecessary shop maintenance.

Lubrication problems confronting American railroads in the operation of diesel locomotives are somewhat different than problems in a manufacturing plant. The main point of railroad lubrication is the diesel engine power plant. This locomotive engine is usually in continuous operation with only "filling station" stops for service. Heavy maintenance is scheduled at annual periods or longer. Locomotives often run 100,000 miles per year with some operating 200,000 miles. Even switch engines operate 50,000 miles per year or more.

Locomotive engines have been designed with lubrication systems capable of operating comparatively long mileages between oil changes. Thirty thousand-mile oil changes are standard practice on many railroads, with some operating for greater distances between changes.

The basic lubrication engineering practice behind this design depends on a large engine crankcase oil reservoir (135 to 300 gallons) and the scavenging of cylinder combustion products away from the crankcase oil. It is common practice to add 10 to 30 gallons of make-up oil per thousand miles of operation. This serves to restore additives and dilute contaminants. Enough oil is added monthly to many crankcases to equal an oil change.

The railroad diesel crankcase lubricant is designed to meet these requirements. Detergent additives keep combustion areas clean, suspending engine sludge until removed by filtration, while the anti-oxidant additives keep the oil stable at the high operating temperatures. Other additives, such as anti-foam agents, corrosion inhibitors, pour depressants, etc. are used frequently. Most diesel oils supplied to railroads today provide efficient lubrication.

The principal problem confronting railroads is the control of crankcase oils in service. Obviously, contaminants must be kept out of the engine system. Fuel, water, suspended carbon, air-borne dust and powdered metals, etc. must be kept at a minimum in the crankcase system. While frequent changes of large, waste-packed oil filters may remove solids, other items (fuel and water) can be best controlled by prevention. Consequently, elaborate inspection systems are used by many railroads to detect fuel and water in samples of crankcase oil for the correction of the leak.

SILICON ANALYSIS

The presence of silicon in oil samples has been interpreted by many authorities as evidence that abrasive silica particles have entered the engine system. Ten parts per million of silicon by weight in the oil has been reported as evidence of abrasives (10) (11) (12). Numerous papers have been offered describing various equipment and techniques for this type of analysis.

Trace element analysis by conventional chemical methods are tedious and often inaccurate in the order of magnitude encountered (parts per million). Silica, in particular, is difficult to measure by wet chemical techniques. To detect and measure wear metals and dirt, many railroads have adopted analysis by emission spectrograph as a routine maintenance aid.

The subsequent analytical values were obtained on a large Littrow prism spectrograph with conventional photographic accessories. The general technique has been published recently by the ASTM in a pamphlet on spectrographic analysis of lubricating oils (3). The method used by the author is described as the "Rotating Platform" technique (4) (5). There are several other accepted techniques in the same ASTM pamphlet, all giving usable results in this type of control.

Several papers have been offered dealing with the theories, techniques and applications of spectrographic results of used crankcase oils (6) (7) (8) (9) (10). To technicians concerned with this type of analysis, it becomes evident that one of the most difficult elements to determine precisely is silicon. Considerable variations in silicon values may occur between the various techniques. Silicate compounds are difficult to excite in an arc or spark and require time to be volatilized to the proper state for light emission. Some of the inconsistencies can be accounted for by variations in methods (ignition temperatures). Variations of silicon values are encountered in duplicate determinations and in successions of crankcase oil samples from the same unit. To

*Research conducted while Engineer of Tests, Missouri-Kansas-Texas Railroad Company, Parsons, Kansas.

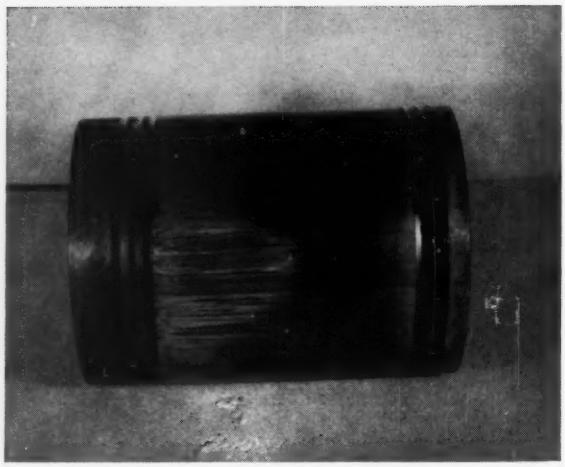

Fig. 1.

better understand the problem, a study was made of the diesel engine, its parts and possible methods by which silicon can enter the lube oil. Obviously, if silicon measurements are to be indicative of air-borne abrasives, other sources of silicon must be allowed for or eliminated.

Several years ago, during a period when many spectrographic analyses were made to control a serious bearing corrosion situation, it was noted that whenever abrasive silica enters one type of engine, a scuffing wear began that could be arrested only by the disassembly of the engine (11) (12). Opinions were offered that silica must be kept from the engine system at all costs. To detect the condition may be too late for corrective action.

This did not correlate with subsequent observations for all types of units. Another pertinent question was the significance of the various levels of silicon measured. A generally accepted interpretation has been that silicon from 0-10 parts per million of the element by weight was of little concern, 10-20 p.p.m. could be significant, 20-50 p.p.m. a serious condition, and over 50 p.p.m. an emergency.

Appreciable cylinder wear and scuffing have been noticed in units where oil samples have not shown high silicon values. Other units with appreciable silicon found in the oil samples have been found in satisfactory condition with little visible abrasive wear. Another variable has been the efficiency of the oil filter system in the removal of the actual abrasive particles from the crankcase oil. It has been noticed that a change of *oil filters* can reduce silicon content of the lube oil. Obviously, the detection of abrasive silica in a diesel engine crankcase oil sample depends on sampling the unit while the "sand" is coming in through the air stream and before the filters can strain the abrasives from the oil. A change in locomotive service conditions (from dusty to clean areas) can easily alter the silicon values determined.

SOURCES OF SILICON CONTAMINATION

To better understand the problem, a study was made to locate all possible sources of silicon in a crankcase oil. These are listed as follows:

1. In the new lubricating oil (anti-foam additives).
2. In gasket cements and gaskets (silicones and silicates).
3. In the air-intake system (silica particles).
4. In the diesel fuel (catalyst and dirt).
5. In the cooling water treatment chemical (silicates).
6. In the engine parts — cast iron (metal component).
7. As miscellaneous contamination (dirt).

1. Anti-foam Additives—Several brands of diesel crankcase oils contain measureable silicon. This is reported to be from the use of silicone anti-foam agents. Table I lists typical values obtained on oils currently purchased. Several years ago an oil shipment was found with over 100 parts per million silicon. When strained through a 100 mesh screen, the residue on the screen resembled caviar particles. It was traced to a refinery error in adding an excess of anti-foam agent. Most oils containing the anti-foam silicone seem to lose the silicone in service. This is illustrated by Table II. The necessity of anti-foams in detergent diesel oils was illustrated recently. A sudden increase in oil consumption of one brand of oil was traced to ineffective anti-foam. Additions of silicone anti-foam concentrate to all locomotive crankcases and to the oil in stock quickly remedied the situation.

2. Gasket Materials—Some gasket cements contain from 5 to 15% silicon compounds. Replacement of assemblies and engine rebuilds are often followed by silicon values in the oil. The amount of silicon from this source is usually below 10 parts per million in the oil sample. When coupled with anti-foam silicon, it can give a false indication of abrasives in newly rebuilt engines. Silicon from this source, as that from anti-foam agents, is of no wear consequences, except for the interference with interpretations of analyses. Silicone gaskets are also used in diesel engine systems. Table III gives a case history where the silicon values may come from the silicone gasket seals. No silicon can be detected in the chromate water-treating chemical.

3. Air-borne Abrasives—The critical source of abrasive silicon is in the silica from the dust along the railroad right-of-way carried in through the engine air-intake system. This "dust" material may consist of other elements, such as calcium, magnesium, aluminum, titanium and other common mineral elements. Most dusts contain appreciable amounts of silica, so that analysis for silicon is an approximate measure of the abrasives present. Table IV gives an illustration. The principal wear zone for this silica is in the combustion zone (Fig. 1). Large abrasive particles in the crankcase can cause bearing wear (Fig. 2). In the case of bearings, the scoring may also be done by metal particles. Some railroads advise an oil change to remove the abrasives. Others rely on oil filter changes to remove the silica. All railroads agree that the air filters should be changed or maintained to stop the intake of the abrasive into the engine. This dust can be present in large amounts, depending on service conditions. A railroad, at one time, "tested" for sand in the oil by the engine dip-stick, indicating the abrasives settled in the crankcase.

4. Fuel Catalyst—Recent investigations of diesel fuel show that appreciable amounts of trace elements can be detected in the fuel itself. In the case of one heavy recycle stock from a catalytic cracking unit, a silicon-containing catalyst was found to be present, suspended in the fuel in measureable quantities. Operation of this fuel in a diesel locomotive in yard switcher service for six months resulted in the rings and liner worn completely beyond re-use (Fig. 3). The top compression ring was reduced 30% in thickness. This was a special fuel service test to investigate the value of this fuel for railroad diesels. It may be significant that conventional fuels, meeting all current specifications, have detectable and sometimes measureable amounts of silicon present. This is presumably from traces of refinery catalysts. It has also been identified in diesel fuels delivered by pipe lines as a dirt contamination. There are other non-silicon catalysts, such as aluminum compounds, that could be classified as abrasives. Very little work has been published on this subject. The silicon values in crankcase oils from this source can be from a few parts per million to the extreme of 20 to 40 p.p.m. when using fuels containing appreciable amounts of catalyst fines. (Table V).

5. Water Treatment Chemicals—Water leaks into the crankcase system result in water evaporation, leaving the water treatment chemical in the oil. One of the widely used borate-type compounds contained silicates. Some of the chromate-type compounds also have contained silicates in the past. Present products are silica-free. These silicates are not considered harmful as abrasives. The oil sludge created by the water leak may deposit on the oil filters, coat the engine side walls and plug the oil strainers. It is undesirable, but should not be classed as air-borne abrasives. Care must be taken to examine the complete spectrographic analysis to prevent incorrect interpretations. The silicon values may be from 25 to 50% of the boron values or from 5 to 20% of the chromate values, depending on the ratio present in the water treatment chemical. Silicon from this source may be as high as 50-100

TABLE I
Silicon Content of New Diesel Crankcase Oils

Oil Brand	Visc. Index	Viscosity SSU @ 210°F	Elements in Parts Per Million Si	Fe	Ca	Zn	Ba
A	71	78.4	4	3	260	6	—
B	74	76.6	8	3	320	1120	—
C	99	80.6	7	3	220	730	1350
D	62	77.0	12	4	1070	6	—
E	49	77.0	6	3	730	—	—
F	93	75.6	—	—	—	—	860
G	87	83.0	4	2	—	—	—

Note: All oils current receipts December, 1956.

TABLE II
Loss of Antifoam Silicone Content of Oils in Service

Sample	Mileage	Elements in Parts Per Million Si	Fe	Cu	Pb	Cr	Al	Ca
1	New Oil	12	4	—1	—1	0	—1	1070
2	6,000	6	2	2	—1	0	—1	1030
3	12,000	4	4	3	—1	0	—1	1030
4	18,000	1	4	2	—1	0	—1	980
5	24,000	1	3	2	—1	0	—1	950

Note: —1 indicates element present but less than one part per million.

TABLE III
Silicon in Crankcase Oil From Silicone Gasket Wear During Water Leaks

Sample	Oil Mileage	Elements in Parts Per Million Si	Fe	Cu	Pb	Cr	Ag	Ba
1	New	4	1	2	1	0	1	1900
2	2,000	4	11	2	1	0	1	1900
3	6,000	4	50	8	7	43	5	1750
4	11,000	10	44	5	2	67	4	2000
5	16,000	13	61	7	5	75	5	2050

Note: The present chromate water-treatment compound contains no detectable silicon compounds.

TABLE IV
Silicon From Air-Borne Dirt in Crankcase Oil Samples

Sample	Oil Life	Elements in Parts Per Million Si	Fe	Cu	Pb	Cr	Al
1	14 Months	1	12	2	1	6	1
2	15 Months	40	66	12	6	3	7
3	15¼ Months	10	17	8	8	11	2
4	15½ Months	4	13	7	4	10	3

Note: Air-intake filters on yard switch unit serviced and oil filters changed. Condition cleared. Unit still operating without distress.

TABLE V
Silicon in Crankcase Oil Samples Presumably From the Fuel Used

Sample	Oil Life	Elements in Parts Per Million Si	Fe	Cu	Pb	Cr	Ag	Ca
1	New Oil	3	2	—1	0	0	0	330
2	11 Days	10	12	4	4	0	1	330
3	35 Days	22	80	13	6	0	1	310
4	49 Days	36	98	8	7	0	2	280
5	57 Days	46	93	22	8	0	4	250
6	85 Days	33	145	15	1	0	6	210

Note: Repeated checking and maintenance of the air filter system had no effect on the silicon content in the oil.

TABLE VI
Silicon In Crankcase Oil From the Silicates in the Water-Treatment Chemicals During Water Leakage

Sample	Oil Mileage	Elements in Parts Per Million Si	Fe	Cu	Pb	B	Ag
1	New Oil	6	2	0	0	0	0
2	2,000	17	15	2	1	47	3
3	6,000	30	33	6	1	76	7
4	18,000	26	65	10	2	70	5
5	24,000	60	103	7	2	135	6
6	28,000	72	82	5	2	196	7
7	32,000	155	175	6	2	260	5

Note: Data 30 months ago. After repeated search for leak, engine block found cracked.

TABLE VII
Silicon From Unknown Source

Sample	Oil Life	Si	Fe	Cu	Pb	Cr	Al	Ca
1	67 Days	6	6	2	1	23	1	790
2	82 Days	500	650	17	20	180	170	920
3	3 Days	147	230	6	10	66	49	1170
4	2 Days	32	70	2	7	35	10	1100
5	9 Days	50	102	4	9	80	12	1270
6	13 Days	52	26	4	2	50	5	820
7	17 Days	30	10	2	1	43	3	560

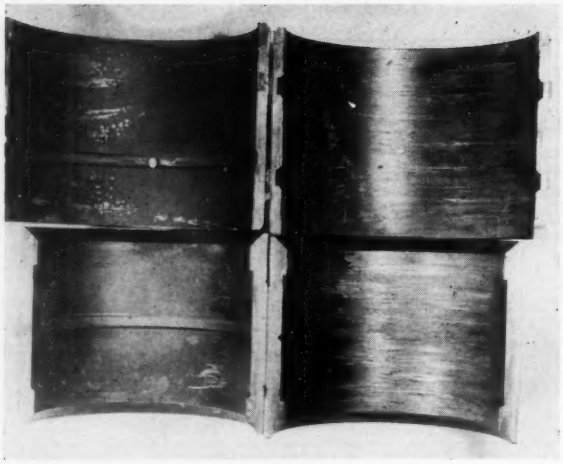

Fig. 2.

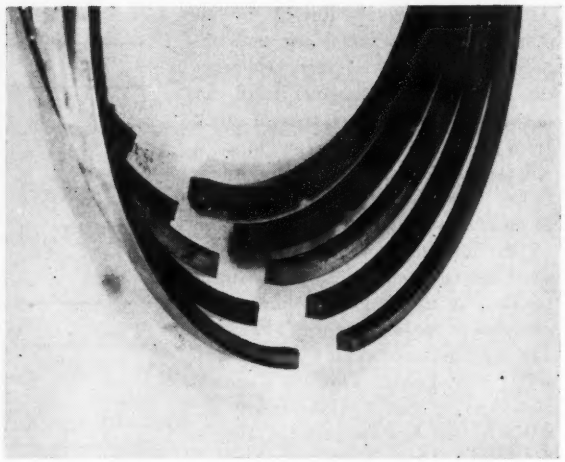

Fig. 3.

parts per million. (Table VI).

6. Miscellaneous—Some miscellaneous sources of silicon contamination are: air-box sludge dropping into the crankcase on an assembly change, cleaner compounds left in engine parts after reclamation, dust entering crankcase during maintenance, and dirt in the oil filter media. Each of the foregoing sources has been experienced during several years of analyzing crankcase oil samples. These are fortunately infrequent in occurrence. Occasionally large amounts of silicon are found in oil samples with no resulting engine distress or explanation of the source. (Table VII).

USE OF SILICON VALUES

The interpretation of silicon analytical values depends on the proper assignment to the source. Only three of the sources of silicon mentioned are considered abrasive: air-dust, catalysts and dirt. The usual maintenance for control of abrasive silica is a change of air filters and oil filters with a quick resampling of the oil for a retest after corrections are made. Corrections cannot always be made immediately, as the locomotives may be at a location inconvenient for such maintenance.

Modern railroad air-filter maintenance is designed to maintain efficient filtration at all times. Frequent changing of air-filters is enough to prevent air-borne abrasives from entering the engine system. Under present practices, it is unusual to find abrasives in an engine system. Care must be taken not to cause undue maintenance repairs from the misinterpretation of silicon values.

Another use of the silicon values is to compare the efficiency of different air-filter systems. Impingement-type, metal-screen air filters were first used on railroad diesels. As new "cyclonic" and "oil-bath" air filter systems were devised, it was practical to use silica values to rate the efficiencies of these systems. Although actual proof lies in wear measurements of component parts, this requires many months of testing. The reduced silica values of these new systems (when properly maintained) are very significant when compared with the former panel impingement-type filters. To date, it has required complete breakdown of these filter systems to permit any appreciable amount of abrasive silica to enter the engine system. These air filter systems are costly but are being installed on many railroads as rapidly as economics permit. Silica values in the oil will continue to be significant after these more efficient air filter systems are placed on every locomotive. Often, the only way failure of air filters is found is by the sudden appearance of silicon in the oil that cannot be explained from other sources. Failures of both kinds of the above mentioned air-filter systems have been encountered in test observations.

SUMMARY

Air-borne abrasives can be controlled in a railroad locomotive system by analysis for silicon. There are a number of possible means by which silicon compounds may enter the lubricating oil, each of which must be considered to reach a valid interpretation of the data. Silicon analyses can assist the maintenance of diesel locomotives in service and in evaluating the efficiency of air-filter systems.

BIBLIOGRAPHY

1. Meeker and Pomatti, "Spectrographic Determination of Trace Elements in Lubricating Oils", *Analytical Chemistry*, Volume 25, Jan., 1953, pages 151-154.
2. Karchmer & Gunn, "Determination of Trace Metals in Petroleum Fractions", *Analytical Chemistry*, Volume 24, Oct., 1952, pages 1733-1741.
3. "Suggested Methods for Spectrochemical Analysis of Used Diesel Lubricating Oils", American Society for Testing Materials, Sept., 1956, pages 21-26.
4. Lewis, "Spectrographic Oil Analysis", *Railway Purchases and Stores*, Oct., 1954, pages 76-81.
5. Rozsa and Zeib, "Trace Determinations in Lube Oils", *Petroleum Processing*, Nov., 1953.
6. "How the Spectrograph Helps Keep Pennsy Diesels on the Road", *Railway Age*, May 28, 1956, pages 34-36.
7. Sennstrom, "Diesel Maintenance Control by Spectrographic Means", SAE Diesel Engine Meeting, Oct., 1952, Paper #845.
8. Mengle and Kathan, "The Spectrograph as a Diesel Engine Trouble-Shooter", Fourth Annual Conference, American Association of Spectrographers, Chicago, May 1, 1953.
9. McBrian and Atchison, "Practical Use of the Spectrograph and Electron Microscope for Study of Diesel Engine Conditions", SAE Diesel Engine Meeting, Oct., 1952, Paper #843.
10. Barth, "Quantometer Speeds Evaluation of Locomotive Lubricating Oils", *Railway Locomotives and Cars*, Jan., 1957, pages 43-44.
11. "Symposium on Spectrographic Analysis of Diesel Engine Lubricating Oil", American Locomotive Company, May, 1952.
12. "Symposium on Diesel Locomotive Engine Maintenance", American Locomotive Company, May, 1953.

Cutting Fluids: Fundamentals and Laboratory Evaluation

L. H. Sudholz, Socony-Mobil Oil Co., Flushing, N. Y.

Many competent lubrication engineers, who regularly make firm recommendations of lubricants, and perhaps even suggest certain design changes for a wide variety of applications, including turbines, compressors, gasoline and diesel engines, hesitate to become equally involved in metal cutting applications. This reluctance is understandable to some extent because of the large number of variables involved in metal cutting.

These include composition, hardness, heat treatment and grain size of the work material; composition, hardness and cutting angles of the cutting tools; cutting conditions — including feed, speed and depth of cut; and finally, cutting fluid with respect to type, volume, pressure and direction of flow. However, experience has shown that recommendation of a reasonably satisfactory cutting fluid can usually be made with a fairly complete understanding of the fundamentals involved and a careful study of the metal cutting operation in question.

This article will concern itself with fundamentals of the metal cutting process, nature of the lubrication problem, effect of cutting fluids, and means of laboratory evaluation.

FUNDAMENTALS OF METAL CUTTING

Some of the main aspects of machinability are:

1. Tool Life
2. Surface Finish
3. Tool Wear
4. Power Required

Cost of the metal cutting operation is of prime importance. Long tool life is desired since, in addition to the cost of replacing and regrinding cutting tools, down time of machine tools means loss of production. Surface finish requirements are usually specified by the customer and vary with the nature and final application of the part being manufactured. Tool wear is important because of tool materials cost and the amount of regrinding time. Of course, with the new "throw away" type tool inserts, the latter is not a factor. In most industrial applications, power requirements are not important. However, they are an indication of a metal cutting operation's efficiency and have been used for this purpose by a number of investigators.

Since principles of metal cutting are generally the same, regardless of tool type used, study of a single point turning tool offers the simplest means of demonstrating the mechanism of this operation. Such a single point turning tool is shown in Fig. 1, side and back rake angles and end and side clearance angles being indicated.

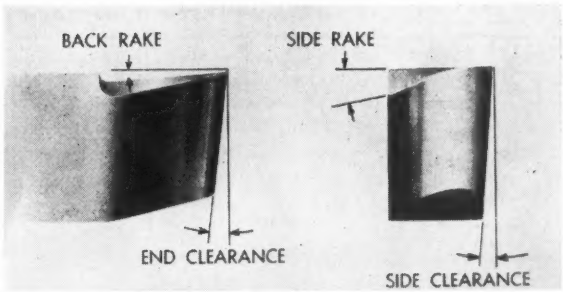

Fig. 1. Tool Angles.

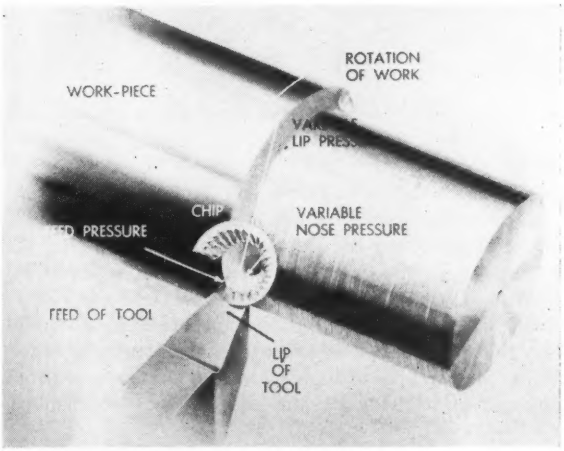

Fig. 2. Cutting Pressures.

Magnitude of the angles depends on the type of metal and machining conditions. Soft, draggy metals require sharper angles than hard, clean cutting metals. Optimum results can be obtained only with proper selection of tool angles for the particular metal involved. This type of formation is available in many metal cutting handbooks.

In Fig. 2, a simple turning operation with a single point tool is shown, with three different pressures acting on three different areas of the tool. Tangential or variable lip pressure is produced by irregular metal flow (chip on the tool). Pressure at the nose of the tool (radial) is due to rubbing and/or tool deflection. Pressure on the side of the tool (longitudinal or feed) is due to rate of feed. Relative magnitude of these pressures, as

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determined during an investigation of a high speed turning operation, is shown below.

Relative Pressures on Cutting Tool	
Radial (Nose)	10%
Tangential (Lip)	100%
Longitudinal (Feed)	40%

Radial pressure is only 10% of the tangential pressure, whereas the longitudinal (feed) is 40%. Absolute values of the pressures vary with type of metal machined, feeds, speeds, and depth of cut. With certain alloy steels, tangential pressure may be as high as 400,000 psi.

In addition to high pressures, high temperatures are also developed in metal cutting operations. For example,

TEMPERATURES IN STEEL CUTTING @ 400 SFM

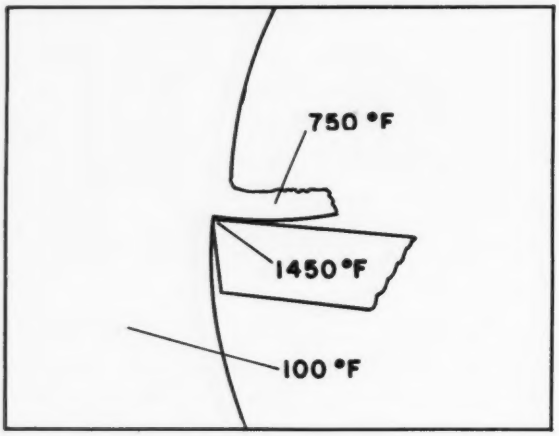


Fig. 3.

Fig. 3 shows the milling of a certain steel at 400 SFM, with no cutting fluid, and indicating relative temperatures of the chip, cutting edge of the tool and workpiece. At cutting edge, the maximum temperature is 1450°F., whereas temperatures of chip and workpiece are 750°F. and 100°F. respectively. It is highly desirable to maintain tool temperature as low as possible, since, as noted in Fig. 4, hardness of high speed steel decreases with an increase in temperature, the change being particularly

EFFECT OF TEMPERATURE ON TOOL HARDNESS

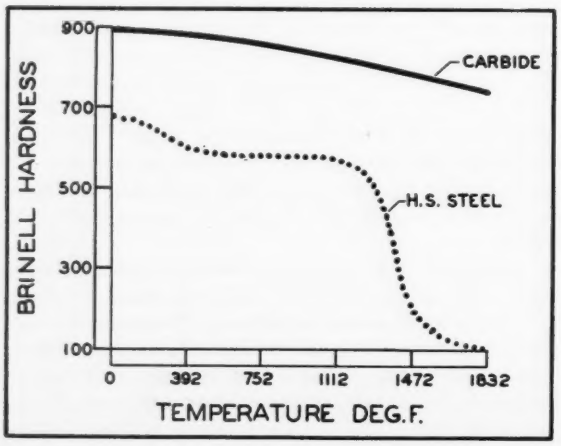


Fig. 4.

abrupt between 1200 and 1500°F. Hardness of carbide tools decreases at a much lesser rate with increase in temperature, and there is no abrupt drop. This explains the need for cooling, especially when high speed steels are used, to prevent softening with resultant abnormal tool wear. It also shows why carbide tools can sometimes be used dry with satisfactory results.

In general, the amount of heat contained in chips, workpiece, and tool is practically constant. At higher speeds, the amount of heat in the chips is increased, while heat in the tool and workpiece is decreased. At high speeds, tool-chip interface temperature usually rises while average chip and workpiece temperatures remain con-

DISTRIBUTION OF HEAT

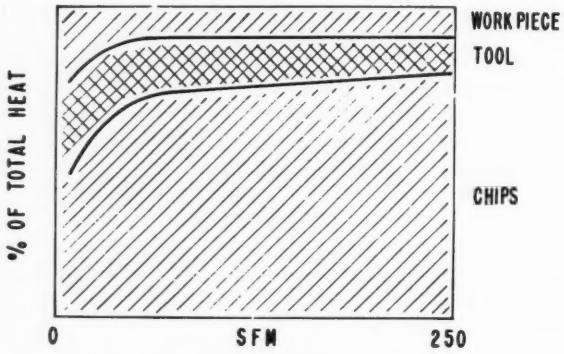


Fig. 5.

stant. At higher speeds, greater amounts of heat are present in the chips because heat has less time to be conducted from chip to tool and workpiece. As an example, in a high speed turning operation (15,000 SFM) on aluminum, the temperature of the chip is quite high but the workpiece is cool to the touch. While thick chips have a lower temperature than thin chips, the percentage of total heat in the chips is greater when they are thick. Approximately, 95% of the work performed in metal cutting ends up as heat.

BUILT-UP-EDGE

In practically all machining operations, a certain

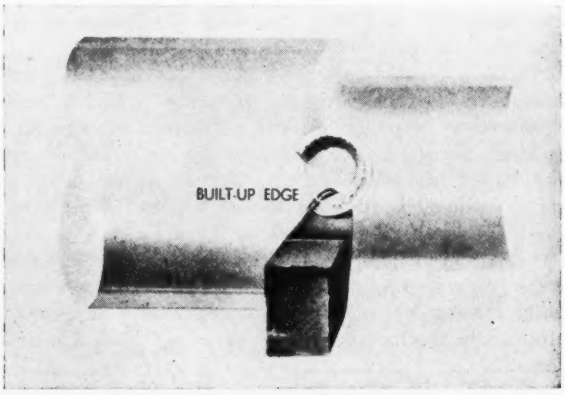


Fig. 6.

amount of semi-mobile material — the built-up-edge — accumulates at the cutting edge of the tool. It represents particles of chip metal transferred to the tool face as a result of pressure welds. Because of strain hardening and hardness of built-up-edge, metal in the chip and that near the finished surface is usually greater than that for the metal before machining (Fig. 7). In this case initial hardness of stainless steel was 240 BHN. Chip and finished surface have hardened considerably, but the built-up-edge approaches tool steel in hardness (550 BHN versus 650 BHN for tool steel), all as a result of work hardening.

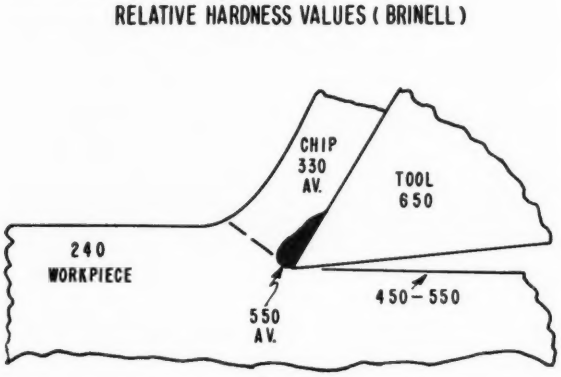


Fig. 7.

The built-up-edge normally welds to the tool and alternately accumulates and sloughs away with the chips. Sloughing of built-up-edge is indicated in Fig. 8. This shows the under side of two chips, the lower produced in machining a clean cutting material and the upper in

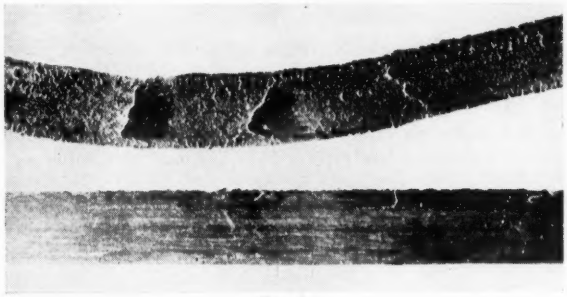


Fig. 8.

machining a soft, ductile steel. The former is smooth and shows no build-up particles, while the latter indicates build-up accumulation that has periodically sloughed away with the chip. If the built-up-edge is allowed to become too large, particles of it may slough off with the work, causing poor finish and excessive wear of the tool's nose.

All tool wear may be attributed to:

1. Built-up-edge sloughing with chip along face of tool.
2. Built-up-edge sloughing with workpiece, wearing the nose of tool.
3. Hard carbides in workpiece or hard chip surface (strain hardened) causing abrasion.
4. Instantaneous welds formed when finished surface or chip slides across tool face.

As noted in Fig. 9, accumulation of appreciable build-up occurs in machining soft, draggy metals which localizes rubbing action of the chip at an appreciable distance from the tool's cutting edge. Point of maximum tool temperature is, accordingly, removed from the cutting edge, and the cutting edge's resistance to wear and breakdown is improved. This condition tends toward long tool life. In machining clean cutting metals, as shown in Fig. 10, lack of appreciable build-up tends to localize the chip's rubbing action at or near the tool's cutting edge. This brings maximum tool temperature close to the cutting edge, decreasing its resistance to wear and breakdown — and tending toward short tool life.

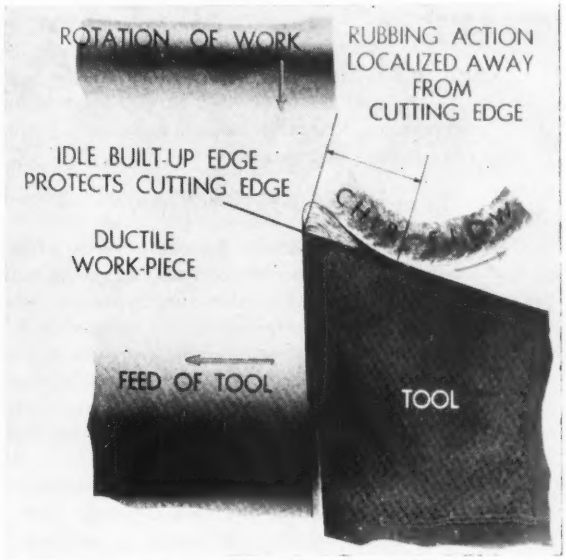


Fig. 9. Effect of Appreciable Build-up on Tool Life.

Accordingly, in all metal cutting operations, build-up-edge control is of utmost importance in obtaining maximum tool life with the required finish.

Unless a fine wheel is used for finishing, a ground tool may have a relatively rough surface. Under these conditions where friction between chip and tool is great and temperature is high, the tendency toward welding is increased and tool life is shortened. Appreciable im-

Fig. 10. Effect of Negligible Build-up on Tool Life.

provement in cutting conditions can be effected by honing the tools. In one instance, it was found that by finishing the tool grinding using a 150 grit instead of a 60 grit wheel, tool life was increased from two hours to 10 hours in turning stainless steel.

In most cases build-up is semi-mobile and, when the cutting operation is stopped, accumulated build-up on the tool goes off with the chip. When there is appreciable build-up on the tool at the cutting edge, the chip contacts the tool some distance behind the cutting edge. At that point, resultant wear forms a crater while the cutting edge is protected. Tool failure usually does not occur until the crater wears back to the cutting edge.

Actual tool failure occurs when wear on the nose and face of the tool has proceeded to the point where dimensions can no longer be maintained, the original cutting edge having disappeared.

LUBRICATION REQUIREMENTS

It has been shown that at the cutting edge of the tool, the conditions which exist include high local temperature (may approach 1500°F), high pressure (possibly as high as 400,000 psi) and highly stressed metal. In addition, the newly cut or "nascent" surface is free of contaminants, such as oxides. All of these conditions promote rapid reaction between cutting fluid and metal work material. In order to be effective, the cutting fluid must possess the following characteristics:

1. Adequate Pressure Resistance — minimizes friction between chip and tool face and prevents periodic seizure. It results in reduced wear, less cratering and heat generation, and more effective cutting by increasing the shear angle.
2. Proper Anti-Weld — controls size of build-up.
3. Adequate Lubricity — minimizes development of frictional heat, and hence, wear, principally in the boundary area, and thus assists in maintaining dimension and finish.
4. Maximum Cooling Ability — tends toward low tool temperature, prolonged tool life and maintains dimensional accuracy.

Friction between chip and tool plays an important part in the cutting process. It may be reduced by the following means:

1. Improved tool finish
2. Increased rake angle
3. Increased cutting speed
4. Use of low friction workpiece such as leaded steels or screw stocks, or appropriate tool material, such as carbides
5. Use of a cutting fluid.

About 75% of the heat developed in metal cutting is caused by metal deformation. Only 25% is due to friction between chip and tool. The former can be varied by changing the shear angle and the latter by changing cutting fluid characteristics. However, as friction is reduced, the shear angle becomes larger (more efficient cutting) causing less heat from metal deformation because of less work being performed. Use of an effective cutting fluid may cause improvements greater than normally expected simply by reducing friction.

Fig. 11 shows the three zones of major interest in a machining operation. First is the zone of shear where plastic flow characteristics of the metal are of most concern. Second is that of friction between tool and work. Third is that of the finished surface of the workpiece.

As friction is decreased in Zone 2 as a result of use of a more effective cutting fluid, the shear angle ϕ, made by the shear plane with the horizontal, becomes greater, resulting in more efficient cutting.

CUTTING FLUIDS

Cutting fluids normally employed in the machining of metal may be classified broadly as non-soluble and soluble. The former are blends of mineral oil with other materials, not emulsifiable with water and used as such. Soluble oils are dispersible in water and are used in the form of emulsions. Actually, some of the newer non-petroleum products form solutions, rather than emulsions, with water.

Non-soluble cutting oils may consist of mineral oils, fatty oils, or other oiliness additives and compounds. The basic materials used in these combinations are as follows:

A. Mineral Oils
   1. Straight
   2. Sulfurized
   3. Chlorinated
   4. Sulpho-Chlorinated

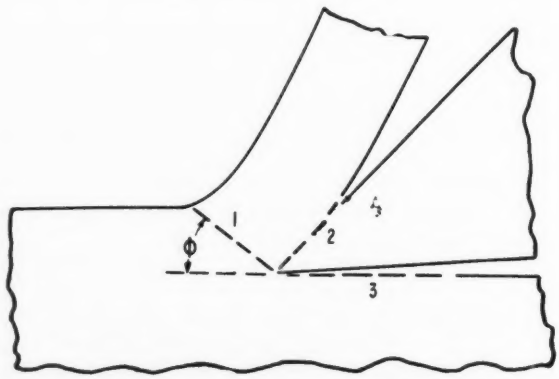
B. Oiliness additives
   1. Fatty Oils
      a) Straight
      b) Sulfurized
      c) Chlorinated
      d) Sulpho-Chlorinated
   2. Synthetics

C. EP Compounds containing sulfur, chlorine, phosphorus, etc.

Obviously, a large variety of combinations of the above materials could be employed in blending cutting oils. Following are typical compositions of soluble cutting fluids.

1. Conventional soluble oils
   Emulsifiers plus mineral oil

ZONES OF INTEREST



1 SHEAR
2 FRICTION
3 FINISH SURFACE

Fig. 11.

Fig. 12. Chip and Cutting Tool.

2. Heavy duty soluble oils
   Emulsifiers plus mineral oil plus additives to impart anti-weld and oiliness characteristics
3. Non-petroleum water-soluble cutting fluids
   Water solutions of soaps, inorganic salts, rust inhibitors, etc.

Generally speaking, soluble cutting fluids are preferred to non-soluble products for high speed and roughing operations where heat removal is more important than lubrication. For these applications, water-containing fluids are superior because of their greater heat removing ability.

Lubricating Films

A fluid film cannot exist because of high pressures and temperatures between chip and tool, therefore there exists an extreme condition of boundary lubrication rather than hydro-dynamic lubrication (Fig. 12). There are several theories regarding the manner in which cutting oil is introduced into these high pressure areas. One theory is that the underside of the chip is always sufficiently rough to provide a large number of capillaries through which cutting fluid, or more logically, decomposition products of the fluid, reach the high pressure area on the tool's face.

Extreme pressure agents are used in cutting fluids because of high temperatures and pressures. These materials, many of which are sulfur and/or chlorine-containing compounds, are effective under these conditions since they form heat and pressure resistant films. Films of sulfides and chlorides actually prevent metal to metal contact. As shown below, their shear strengths are lower than that of pure iron, and hence tend to lower the friction between chip and the tool. Since sulfides have higher melting points than chlorides, sulfur compounds in general are, more effective for heavy duty operations such as threading and broaching. Chlorides tend to reduce friction to a greater extent than sulfides and are useful in many high speed, relatively light duty operations, such as high speed turning, forming and drilling.

Material	Melting Point, °F (Approximate)	Shear Strength, %
Iron	2800	100
Iron Chlorides	500-1200	20
Iron Sulfides	2100-2200	50

Fatty oils and synthetic oiliness additives form iron soaps which also have low shear strengths, but lower melting points than chlorides or sulfides and are not as effective for heavy duty operations.

Active Sulfur and Chlorine

A wide variety of compounds can be used to blend a cutting oil having definite sulfur and/or chlorine content. Performance of the final product depends upon careful selection of proper components. Years ago, it was commonly believed that the higher a product's total sulfur content, the more effective it would be in a machining operation. Only quite recently has it been proved that active sulfur content is of far greater importance. Of course, what is really important is the activity at the temperature of the cutting edge of the tool, which may be in the range of 1000-1500°F. However, since it is impractical to determine active sulfur content under these conditions with ordinary laboratory equipment, a temperature of 300°F has been chosen in the following widely accepted method.

A small quantity of the product is agitated for one hour with copper powder at 300°F. Oil is filtered and the filtrate's sulfur content determined. This represents the inactive sulfur. The difference between this and the total sulfur is the active sulfur content.

While active sulfur content is obviously not an accurate measurement of activity under metal cutting conditions, it does serve as an indication. However, two oils having the same active sulfur content, measured at 300°F., may show entirely different activity at 1000°F. (Fig. 13). This variation is due to temperature-activity characteristics of the different sulfur compounds used.

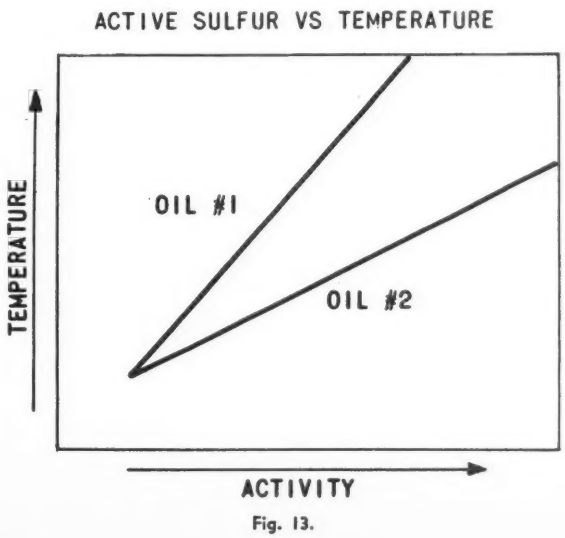


Fig. 13.

Obviously, these two oils would not give the same performance. Likewise, the ratio of active sulfur contents cannot be used to predict performance. In one specific instance, (Fig. 14) an oil with six times the active sulfur content of another showed a tool life of not quite twice as great. Therefore, like many other analytical tests on cutting oils, active sulfur content is only indicative not predictive, of cutting oil performance.

While considerable work has been done in an effort to develop a test for active chlorine content of cutting fluids, at present none is generally acceptable.

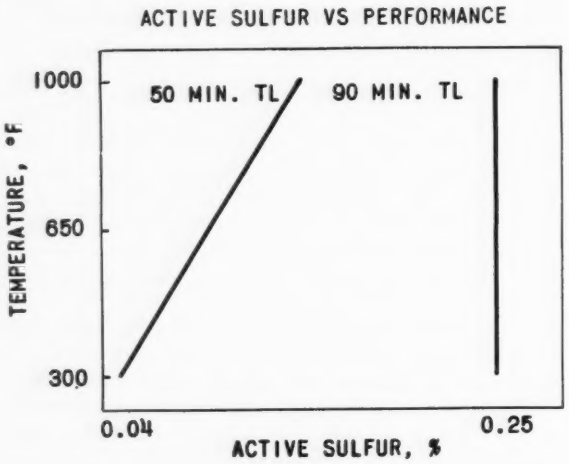


Fig. 14.

LABORATORY EVALUATION OF CUTTING FLUIDS

It has been pointed out that analytical tests are of limited value in predicting a cutting fluid's performance. Likewise, a number of extreme pressure testers, such as the Almen, Falex and Timken have been investigated for this purpose. While much useful information has been obtained from these tests, actual metal cutting operations have proved more accurate. The conditions of high temperature, high pressure and stressed metal might be reproduced, to some degree, by bench tests. However, the newly formed, "nascent" surface, can be obtained only by metal cutting. Therefore, for accurate evaluation, a metal cutting operation is desirable.

1. Threading Tests

Threading tests have been satisfactory in evaluating products under specific conditions. The curve shown in Fig. 15 indicates the relationship of active sulfur content to threading efficiency (based upon power consumption) on seamless tubing, which is approximately equivalent to an SAE 1020 steel. Efficiency varies almost directly with active sulfur content.

In threading SAE 3140 steel, however, there is an optimum active sulfur content, above and below which Performance is adversely affected. Figure 15 shows that about 0.4% active sulfur gives maximum tool life on this rather hard, fairly clean cutting metal. Furthermore, it is evident that there is no correlation between active and total sulfur.

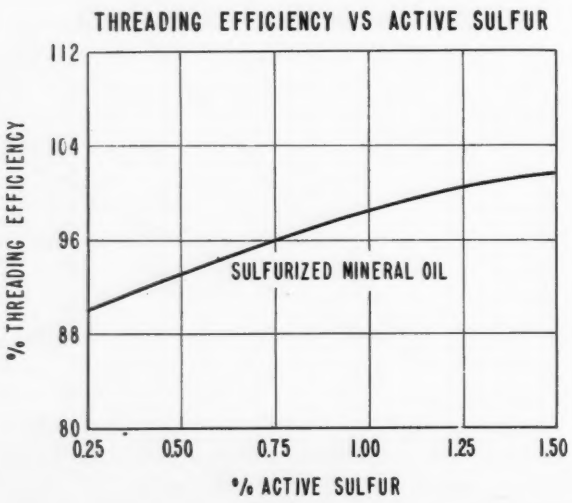


Fig. 15.

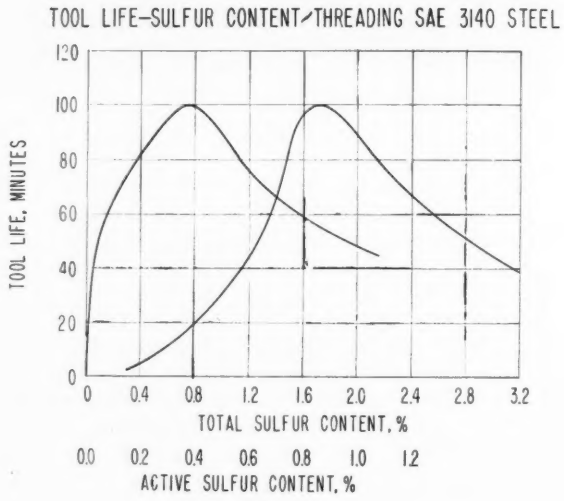


Fig. 16.

2. Drilling Test

An example of the data obtained in a drill life test on SAE 3240 steel is shown in Fig. 17. As the chlorine content of a sulfurized cutting oil is increased, considerable improvement in performance is obtained.

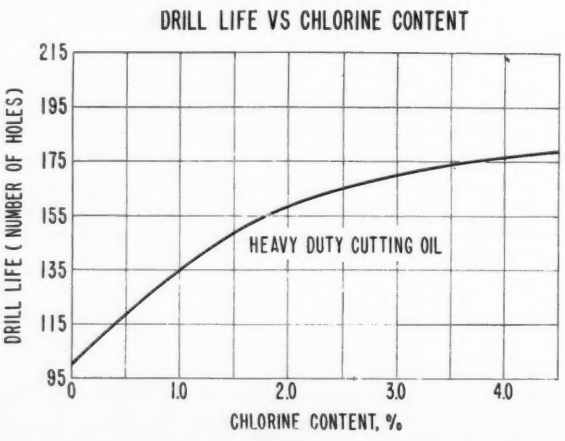


Fig. 17.

3. Tapping Test

Some time ago, the tapping test was selected as one that would be generally satisfactory for evaluating cutting fluids, since it fulfilled the following requirements.

a) Simplicity
b) Speed
c) Economy
d) Small test sample
e) Precision
f) Correlation with field results
g) Severe conditions

The test equipment comprises a small drill press equipped with a floating table. Maximum force during tapping under standardized conditions is indicated on a scale by means of a torque mechanism. A series of holes is carefully drilled and reamed in flat stock consisting of SAE 1020 steel, hot rolled, having a hardness of 120 Brinell. The holes are then tapped, 6 holes with each of 5 taps. Maximum torque developed is indicated on the scale. This torque is then compared with that of a known, or standard, oil.

The tapping efficiency is then calculated from the following formula:

$$\text{Efficiency, \%} = \frac{\text{Torque with Standard Reference Fluid} \times 100}{\text{Torque with Unknown Fluid}}$$

Sample Calculation

$$\frac{68.2 \text{ in. lbs.} \times 100}{72.0 \text{ in lbs.}} = 95\%$$

This test has proved to be quite satisfactory for evaluating cutting fluids because of its simplicity, economy and good precision. The correlation with field experience has been good, especially where severe operations such as threading and broaching are performed on soft, draggy metals. The test was described fully and typical test results were presented and discussed in the May-June 1956 issue of LUBRICATION ENGINEERING.

4. Radioactive Tool Wear Method

The radioactive method is potentially a quick, sensitive and precise means for evaluating the life of cutting tools under commercial service conditions, superior to most tool-life tests as its speed and sensitivity make it unnecessary to accelerate the test by drastically increasing cutting speed or feed. The latter, abnormal condition impair correlation with field results.

RADIOACTIVE TOOL WEAR TECHNIQUE

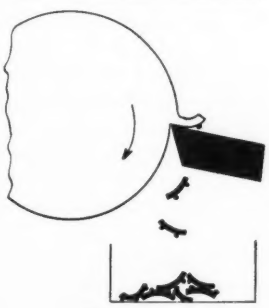


Fig. 18.

Briefly, the principle of this method is the detection of radioactivity in chips cut with an irradiated tool (Fig. 18). Most of the worn particles of the tool adhere to the chips. Therefore, measurement of chip activity collected over a short time period, gives an indication of the tool's degree of wear. Separate tests have established that this tool wear correlates with tool life.

The tool holder is mounted on the lathe. The flange of the holder is bolted to a steel box which is enclosed except for an opening for the workpiece, a drain hole for cutting oil at the bottom, and two inlet oil tubes at the back. The bolt bears against a flattened area of the holder clamp, securing the tool bit tightly during the machining operation. The lower portion of the front face of the box is a door which opens to allow access to the chip-catching drawer. The latter has a wire mesh bottom which permits oil drainage. The entire box is mounted on the turret of the lathe.

Workpieces, which may be of different types of steel, are tubes machined from solid bars. Orthogonal cutting is obtained by feeding the tool perpendicular to the workpiece's direction of motion. Cutting fluid is first fed at a regulated rate in two streams directed at the tool, and then drained from the box into a catch basin.

About 25 grams (approx. 1 ounce) of chips obtained during a few seconds of cutting are removed in the drawer, rinsed with solvent, dried and weighed. The radioactivity is measured by a scintillation counter, which converts nuclear disintegration into voltage pulses counted by a scaler.

The graph shown below (Fig. 19) indicates relative

RADIOACTIVE TOOL WEAR VS CUTTING FLUID ACTIVITY

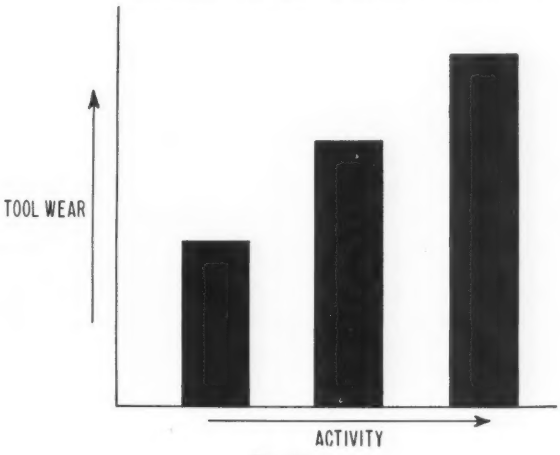


Fig. 19.

rates of tool wear obtained by this method in machining SAE 3140 steel, heat treated, 280 BHN. As in the case of threading tests on this metal, these data show optimum results obtained with a cutting oil of relatively low activity. Too much activity in the product results in high tool wear, or low tool life.

SUMMARY

Metal cutting operations involve conditions of high temperatures and pressures. In most cases, chemical films of sulfides and chlorides are effective for adequate lubrication. Generally speaking, analytical and even bench tests, give only indications of the type of performance that could be expected from a cutting fluid under field service conditions. For accurate evaluations, actual metal cutting operations under carefully controlled conditions are still required. New test techniques, such as the Radioactive tracer method, are rapid, and results correlate with field experience.

Evaluating Cutting Fluids in Accelerated Machining Tests

F. J. Daasch, S. L. Eisler, W. D. McHenry, R. K. Paton
Ordnance Corps, Rock Island Arsenal, Rock Island, Ill.

Studies were conducted to establish the relative performance of three emulsifiable oils and three compounded mineral oils by the use of radioactive tools. A significant difference was found in the rate of tool wear between the mineral oils and the emulsifiable oils; however, there was no significant difference noted between the oils within either group. A parallel study of tangential and feed forces proved insensitive for the conditions of these tests.

For a number of years, it has been common practice to select the proper cutting fluid for a particular operation on the basis of experience with the same or similar materials. Since there are many types and brands available, and in some cases no past experience to draw upon, the user generally has been unable to make the best selection. This has been further complicated by the lack of a standard method to evaluate cutting fluids.

This investigation was conducted to evaluate the performance of cutting fluids by the use of both the radiometric tool wear and the tool force methods. These methods were selected because they are conducted under actual machining conditions and are much less time consuming than the total destruction or wear land methods for the determination of cutting tool life.

Materials Employed

The cutting tools used for this investigation were of the insert-type or, as commonly known, the throwaway-type. A high speed steel of 18-4-1 composition was used for these tests, and all tool bits were cut from the same piece of tool steel. Each tool bit measured ½ inch square by ⅛ inch thick. These were prepared to size by grinding with a 54-grit aluminum oxide wheel. All angles were checked for accuracy by use of an optical comparator. The following effective tool geometry was used:

Back rake	0°	End cutting edge	15°
Side rake	6°	Side cutting edge	15°
End relief	6°	Nose radius	0.005″
Side relief	6°		

The tool bits were irradiated in the nuclear reactor at Oak Ridge for one month. This service had been authorized previously by the Atomic Energy Commission, Isotopes Division and was performed by the Oak Ridge National Laboratory. The tools were held at that laboratory for one week prior to shipment in order to allow for decay of W^{187}. The estimated activity of each tool bit upon receipt was 5.0 mc, consisting mainly of W^{185} and Fe^{59}.

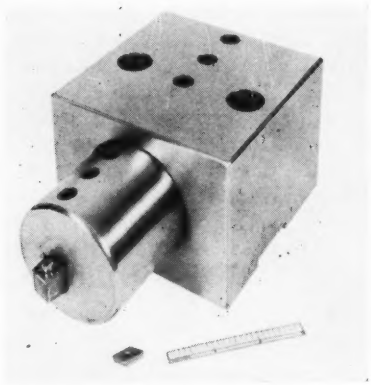


Fig. 1. Tool Post Dynamometer.

The tool bits were held in a special holder for use with the tool-post dynamometer, shown in Fig. 1. The tool-post dynamometer was used to determine the tangential and feed forces simultaneously with the wear measurements. The arrangement of the machining area is shown in Fig. 2, with a portion of the shielding removed for ease of photographing.

The cutting fluids selected for evaluation in this investigation consisted of three emulsifiable oils, designated as A, B and E and three compounded mineral oils, designated as C, D and F. Fluids Coded A and B are 40:1 and 20:1 dilutions, respectively, of the same base oil.

A 16-inch engine lathe with a variable-speed drive was used for all machining work. The test log, 8 inches in diameter and 36 inches long, was FS 4140. It had been annealed previously to a uniform structure with an average Brinell hardness of 187. Photomicrographs of the work material after a picral etch are presented in Fig. 3 at magnifications of X100 and X1000.

Experimental Design

This experiment was designed so that all variables to be studied could be tested without any effect or bias due to uncontrolled variables. The experiment was set up as a Latin Square design. This was a convenient arrangement as six cutting fluids and six cutting tools were to be used. Four cutting speeds were randomized within each cell of the square and later analyzed as a split-plot within the Latin Square design.

The statements and opinions contained herein are not to be construed as being official or reflecting the views of the Department of the Army.

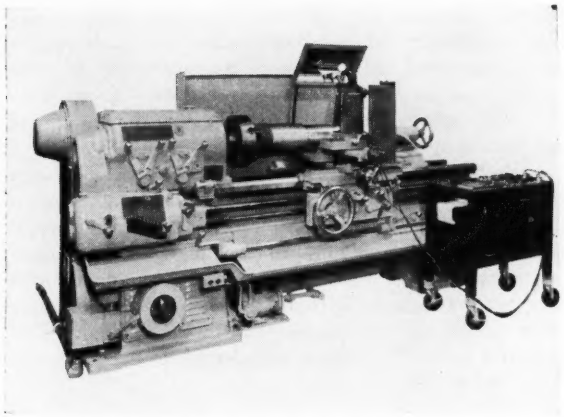


Fig. 2. Machining Set-up.

The final arrangement of the test program, after complete randomization of the square and speeds within the cells of the square, was as shown in Fig. 4. It should be noted that with only four edges available on each tool, one edge was assigned to each one and one-half cells. The tests were run in the order shown, starting at the upper left-hand corner and proceeding downward until the first column (Tool 1) was completed and then continuing with Column 2, and so forth.

This design made it possible to observe if there was a significant difference between tools, edges or fluids, as well as to determine if there was a cutting speed — cutting fluid interaction effect. Six replicates of each test were provided to improve the accuracy of the average experimental values.

Machining Operations

All samples of cutting fluid were prepared in five-gallon lots and pumped from open-top, drum-type containers which served as interchangeable sumps for the circulatory system. This set-up consisted of a centrifugal pump, an overhead flood arrangement, a carriage pan to collect the cutting fluid and a filter to remove the metallic particles from the cutting fluid.

The circulating system was thoroughly flushed after each fluid change with either a cleaning solvent, conforming to Federal Specification P-S-661B, or water, dependent upon the type of cutting fluid which had been previously used. The first pint of fresh coolant to pass through the nozzle each time was discarded in order to remove any trace of the flushing fluid or the previous coolant.

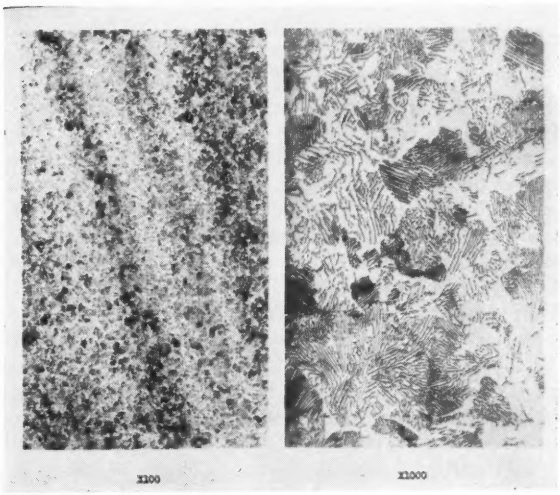


Fig. 3. FS 4140 Photomicrographs.

TOOL NUMBER

	1	2	3	4	5	6
Edge 1	140 120 CF G 80 100	140 120 CF D 100 80	120 100 CF E 140 80	80 140 CF F 100 120	120 100 CF B 80 140	140 100 CF A 120 80
	120 100 CF E	100 80 CF F	140 100 CF C	100 120 CF A	120 100 CF D	120 140 CF B
Edge 2	80 140	140 120	120 80	140 80	140 80	80 100
	120 100 CF A 80 140	120 140 CF C 100 80	100 80 CF D 120 140	140 120 CF B 80 100	140 120 CF F 80 100	80 100 CF E 140 120
Edge 3	140 100 CF B 80 120	140 120 CF E 80 100	100 120 CF F 140 80	140 120 CF C 80 100	140 100 CF A 120 80	80 140 CF D 120 100
	140 100 CF D	80 100 CF A	80 100 CF B	140 100 CF E	80 120 CF C	80 100 CF F
Edge 4	120 80	120 140	140 120	80 120	100 140	140 120
	80 140 CF F 120 100	120 140 CF B 80 100	140 120 CF A 80 100	100 120 CF D 80 140	120 80 CF E 100 140	140 120 CF C 80 100

Latin Square Arrangement
Figure 4

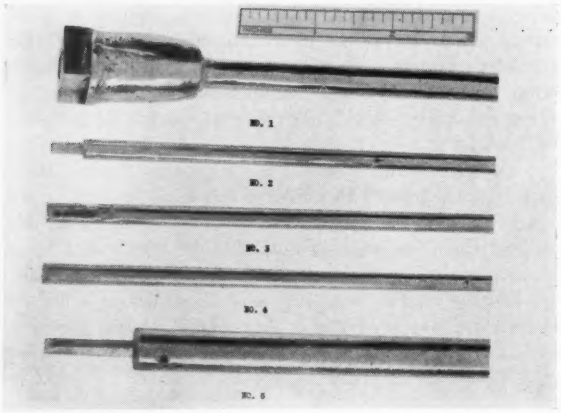


Fig. 5. Handling Tools.

The tool-bit handling devices are shown in Fig. 5. The magnetic carrying tool, No. 1, was used to transport the tool bits between the storage chamber and the tool-bit holder. Tool Nos. 2, 3 and 4 have shafts small enough to slide inside the hollow handle of the carrying tool. Tool No. 2, a hexagonal wrench, was used to manipulate the hold-down screw of the tool-bit holder. Tool No. 3, a small magnet, was used to rotate the tool bits from one cutting edge to the next. Tool No. 4 was used to remove the tool bit from the magnet (No. 1) when the tool bit was returned to storage. Tool No. 5 was used as a hexagonal wrench for use with the set screws which clamped the tool holder into the tool-post dynamometer.

The test log was skinned to a depth of about ¼ inch before the start of the tests to remove the scale and non-uniform material from the piece.

All four cutting edges of each tool bit were "broken-in" for 60 seconds at a speed of 80 fpm, a feed of 0.009 ipr and a depth of 0.0625 inch, as it had been determined that the tool wear becomes constant after that length of time.

All tests were made with a feed of 0.009 ipr, a depth of cut of 0.0625 inch and for 15 seconds duration; however, the chips were collected for only the last 10 seconds of each cut. Tangential and feed cutting forces were obtained for each test cut on a two-channel oscillograph recorder which was operated in conjunction with the tool-post dynamometer.

Counting-Rate Determinations

All chip formations longer than ¼ were broken into lengths of ¼ inch or less. These were then cleaned in a trichloroethylene vapor degreaser to remove any adhering fluid.

After the chips in each sample were thoroughly mixed, three grams of chips were placed in a stainless steel cup. Each of these cups was inserted in turn into the holder shown in Fig. 6. This arrangement was held in the chuck of the lathe, Fig. 7, and rotated at 140 rpm to thoroughly mix and vary the position of the chips during the counting-rate determination.

Counting-rates were determined by use of a mica-end window Geiger-Muller counting tube operated in conjunction with a decimal scaling unit. The tube was wrapped in three layers of 1/16 inch sheet lead to reduce background radiation. In order to maintain the same counting accuracy for high and low activity samples, the time required to totalize 1000 counts with each sample was determined. Background measurements of 500 counts were made after each nine samples. From these data, calculations were made to determine the net counts per minute of each sample.

Preliminary counting determinations which were made on chips obtained from cuts made at 80 fpm indicated that the counting rates were too low for statistical accuracy. Therefore, all 80 fpm samples were eliminated from the analysis. This explains the grouping of nine samples between background determinations as there were only three samples per cell to be counted. This caused a reduction of total samples in the Latin Square from 144 to 108.

RESULTS AND DISCUSSION

The results for the radiometric phase of this investigation have been tabulated in Table I with the counting rates in net counts per minute. In a comparison with the original experimental design shown in Figure 4, it will be noted that there were only three test values per cell instead of four. This difference was due to the elimination of the 80 fpm cutting speed data. In the preparation of the Analysis of Variance Table (Table III), the column totals and row totals were used to determine if there was a significant difference between

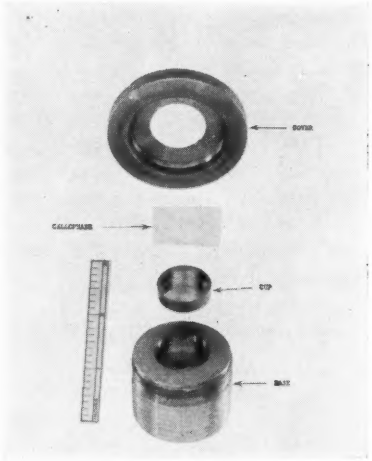


Fig. 6. Sample Holder.

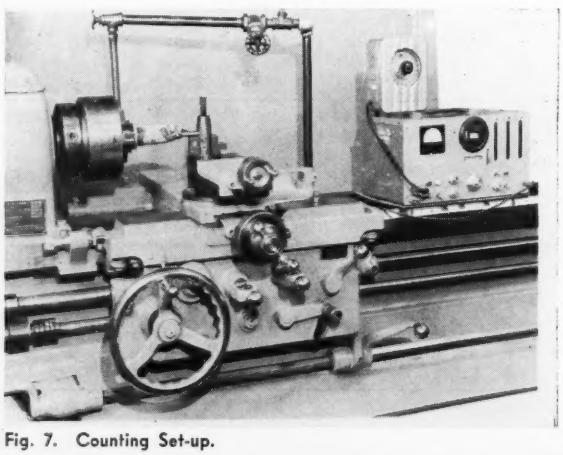


Fig. 7. Counting Set-up.

TABLE I

Net Counts
Per Minute Per Three Grams of Chips

	TOOL NUMBERS						
	1	2	3	4	5	6	
Cutting	Cutting Fluids						Row
Speed—fpm	C	D	E	F	B	A	Totals
100	64.6	11.5	130.0	8.3	105.6	132.9	
120	151.6	200.8	177.9	130.8	207.6	195.7	
140	188.6	233.2	209.1	132.8	235.4	226.0	
Cell Total	404.8	445.5	517.0	271.9	548.6	554.6	2742.4
	Cutting Fluids						
	E	F	C	A	D	B	
100	157.3	14.6	147.6	99.2	54.0	168.6	
120	209.4	152.6	125.2	197.1	125.1	170.4	
140	210.1	174.8	115.4	143.3	141.0	200.5	
Cell Total	576.8	342.0	388.2	439.6	432.1	539.5	2606.2
	Cutting Fluids						
	A	C	D	B	F	E	
100	133.1	128.8	20.0	142.4	79.3	147.5	
120	175.6	121.7	113.3	176.9	151.8	216.0	
140	246.6	148.2	137.6	231.3	164.0	225.1	
Cell Total	555.3	398.7	270.9	550.6	395.1	588.6	2759.2
	Cutting Fluids						
	B	E	F	C	A	D	
100	150.6	202.5	22.7	40.2	102.9	67.5	
120	241.5	249.5	121.7	99.4	149.3	49.1	
140	240.0	264.0	116.6	117.9	207.4	126.6	
Cell Total	632.1	716.0	261.0	257.5	459.6	243.2	2569.4
	Cutting Fluids						
	D	A	B	E	C	F	
100	18.4	225.2	116.9	160.3	45.5	135.2	
120	126.7	256.5	222.2	172.3	89.5	154.8	
140	114.0	270.4	131.6	174.1	107.5	120.7	
Cell Total	259.1	752.1	470.7	506.7	242.5	410.7	2641.8
	Cutting Fluids						
	F	B	A	D	E	C	
100	9.2	225.7	111.7	9.9	130.9	26.6	
120	161.5	278.2	219.5	85.7	216.6	172.6	
140	148.1	305.8	288.0	122.7	242.3	168.3	
Cell Total	318.8	809.7	619.2	218.3	589.8	367.5	2923.3
Column Totals	2746.9	3464.0	2527.0	2244.6	2555.7	2704.1	
						Grand Total	16242.3

TABLE II

CUTTING FLUIDS VS. SPEEDS
Net Counts Per Minute

Cutting	Cutting Fluids						Row
Speed—fpm	A	B	C	D	E	F	Totals
100	805.0	709.8	453.3	181.3	928.5	269.3	3547.2
120	1193.7	1296.8	760.0	700.7	1241.7	873.2	6066.1
140	1381.7	1344.6	845.9	875.1	1324.7	857.0	6629.0
Column Totals	3380.4	3551.2	2059.2	1757.1	3494.9	1999.5	
						Grand Total	16242.3

SUMMARY

Grouping of Cutting Fluids by Total Net Counts
Group 1 (Emulsifiable) — A, B, E
Group 2 (Compounded mineral) — C, D, F

tools and between edges of tools, respectively. It will be noted that the total of Column 2, Table I, which represents Tool No. 2, was much higher than the others. The reason for this difference may be assigned to uncontrolled differences of the tool in preparation which may have resulted in non-uniform positioning during attachment in the toolholder. It may also be noted that some tests have a wide range of values for the six replicates of a test condition. This was expected due to the inherent variation of the test procedure which was the reason for the randomization of the test runs.

Table II tabulates the totals obtained for each cutting fluid at each of the three speeds. It may be noted from the summary that the tool wear for the emulsifiable oils was greater than for the compounded mineral oils. Cutting fluids A and B, which were different dilutions of the same emulsifiable oil, indicated no significant difference in tool wear. This table was also used to prepare the split-plot portion of the Analysis of Variance table.

TABLE III

Analysis of Variance
Based on Radiometric Wear

Latin Square Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio
Tools	46,875.27	5	9,375.05	6.39***
Edges	4,672.73	5	934.55	0.64
Cutting Fluids	200,524.37	5	40,104.87	27.36***
Error (a)	29,342.60	20	1,467.13	
Total	281,414.97	35		
Split Plot				
Cutting Speeds	149,622.27	2	74,811.14	70.12***
Cutting Fl. x S	9,797.44	10	979.74	0.95
Error (b)	61,884.07	60	1,031.40	
Total	502,718.75	107		

***Indicates a very highly significant difference.

The Analysis of Variance is defined as the analysis breakdown of total variability into component parts[1]. Thus, it is possible to determine which variable under study caused the significant difference in the results. The required calculations for the preparation of the Analysis of Variance table are presented in any text on statistics, such as referred to above.

An Analysis of Variance was also made in order to establish the significance of the factors as determined by the method of tool forces. As the results indicated that this method was unable to detect differences either in types of cutting fluid or between cutting fluids of the same general classification, the data have been omitted from this paper.

CONCLUSIONS

The following conclusions may be drawn from the analysis presented in Table III.

1. There is a very highly significant difference between fluids as evident from the high "F" ratio. This was expected in view of the fluids which were examined, namely emulsifiable oils and compounded mineral oils.

2. The "F" ratio also indicates a very highly significant difference between tools. As previously mentioned, this difference cannot be explained as all tools were originally from the same piece and were prepared to the same specification.

3. The very highly significant difference between speeds was expected, as the rate of wear is known to increase with an increase of cutting speed. It was also of interest to note that there was no cutting fluid-speed interaction. This indicates that there was no shift in the relative efficiency of the fluid as the speed was increased. There was reason to believe that such a condition might exist, but the results indicate that based on tool wear a good cutting fluid at one speed can be expected to be equally good at other speeds.

4. The fact that a significant difference existed between fluids was explored further. It is evident from the column totals of Table II that the fluids tend to be divided into two groups; A, B and E in one group and C, D and F in the other group. This corresponds to the original grouping of three emulsifiable oils and three compounded mineral oils. Analysis was made in order to determine if a significant difference existed between fluids A and C, which showed the least and the most wear of their respective groups. The results indicated that at each of the three speeds (100, 120 and 140 fpm), the difference between means was significant. However, additional tests for significance between coolants within the two groups mentioned above showed no significant differences. In summary, this indicates a real difference in rate of wear between water-oil emulsions and compounded mineral oils (the latter group showing the least wear in these tests), but it was not possible to show any difference between fluids of the same group.

5. The results of this investigation indicate that the radiometric method is adequate to distinguish between types of coolants. However, there is reason to believe that with the use of tool bits of higher activity and better counting methods that the procedure can be extended to distinguish between coolants of the same type and serve as an effective method of evaluation.

Acknowledgements:

The authors wish to express their appreciation to Dr. E. H. Jebe, Iowa State College for his help in designing these experiments and to the Ordnance Corps, Department of the Army for permission to publish the information in this paper.

[1] Villars, D. S., Statistical Design and Analysis of Experiments for Development Research, Wm. C. Brown Co., Dubuque, Iowa, 1951, p. 63.

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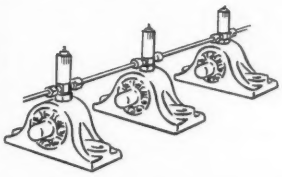

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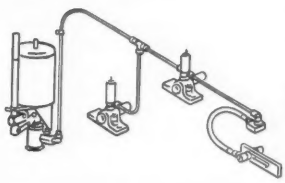

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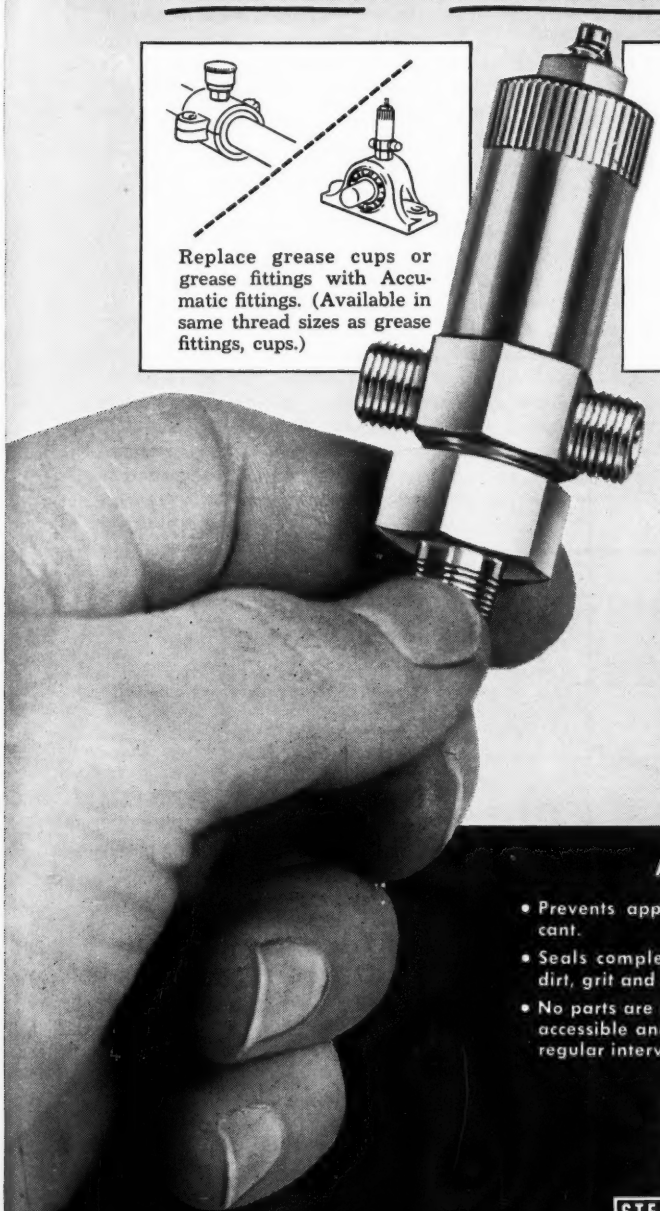

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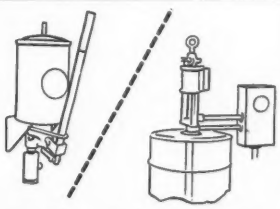

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ASLE News Notebook

Going to Toronto?

Toronto, Canada's capital city with a distinctly U. S. type appearance, is this year's host to the ASLE-ASME joint lubrication conference to be held October 7, 8, and 9 at the Royal York Hotel.

HOW TO GET THERE

Toronto's proximity to the U. S. in miles and in manner of living make it an ideal convention city. For those planning to attend the joint lubrication conference, two railway systems — Canadian National Railways and Canadian Pacific Railway — arrive at Toronto's Union Station across the street from the Royal York. Trans-Canada, American, and Canadian Pacific Airlines serve Toronto with direct transportation to the door of the Royal York.

DRIVING REQUIREMENTS

Driving into Canada is simple if a few rules are followed. Upon reporting to Customs at the Port of Entry (Windsor, most likely), a traveler's vehicle permit, good for six months, is made out. The driver should be sure to carry his state license as well as his automobile registration card. A driver who doesn't own the car must have the owner's written permission and registration card in order to drive the car in Canada.

Tip to dollar-conscious drivers: The Imperial gallon gasoline measure sold in Canada is one-fifth larger than the U. S. gallon, so fewer gallons are needed to fill fuel tanks.

NO PASSPORTS NEEDED

Citizens or permanent U. S. residents require no passports. U. S. citizens should carry identifying papers such as birth certificate, voter's registration, or driver's license. Naturalized citizens ought to carry a naturalization certificate as evidence of citizenship.

AFTER HOURS

After convention hours, Toronto offers plenty of entertainment, all of it within easy reach of the Royal York Hotel (see map). Casa Loma, a 98-room castle combines old-time turrets and wine cellars with modern-day music and dancing. Diner's Club restaurants include the Cork Room (where Esquire Club cards are honored and the Seaway Hotel restaurant. The theatre season should be in full swing, and several theatres are in the immediate downtown area.

WHAT CAN BE BROUGHT IN

Clothing and personal belongings are admitted duty-free. Up to 50 cigars, 200 cigarettes, two pounds of tobacco, and 40 ounces of alcoholic beverages may be included. Gifts brought into Canada may be allowed free entry if a gift's total value, for any one recipient from any one donor, does not exceed ten dollars. Technical papers are duty-free.

WHAT CAN BE TAKEN OUT

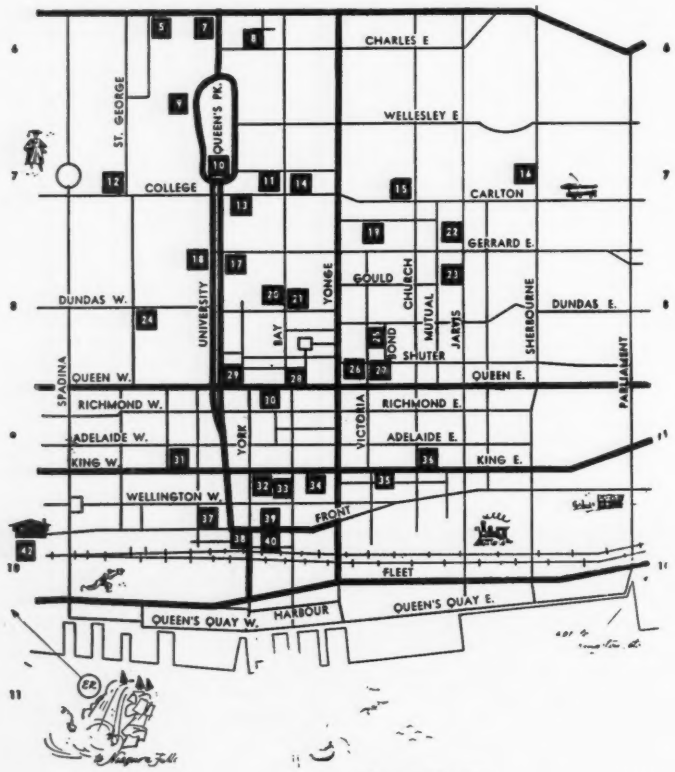
U. S. residents who have remained in Canada at least 48 hours may take back up to $200 worth of merchandise for personal or household use. Up to 100 cigars and one wine gallon of alcoholic beverages may be imported (if state laws permit).

Re-entry to the U. S. can be simplified if:

1—All purchases are listed before reaching border

2—Sales receipts and invoices are kept handy

3—Purchases are packed separately for convenient inspection.



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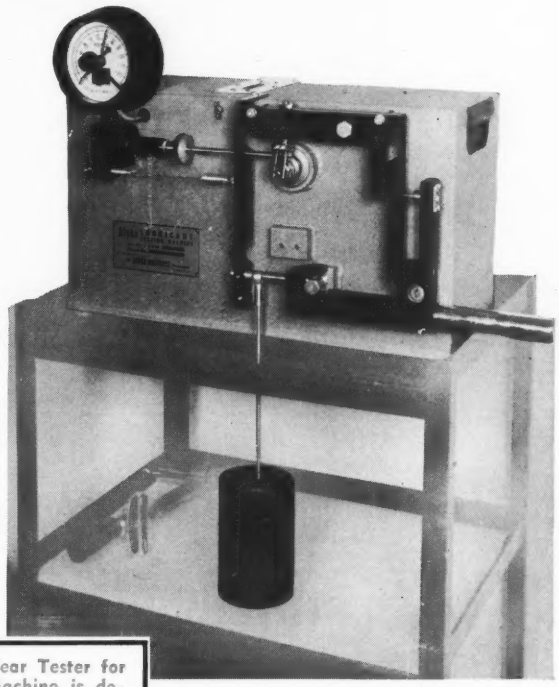
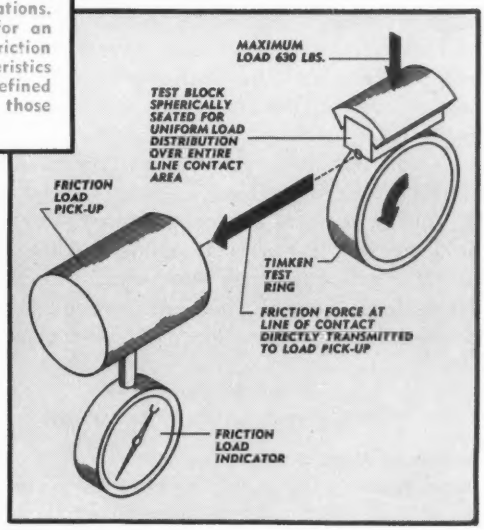
PRECISION TESTING IN THE LOW VELOCITY E. P. RANGE

Admittedly the greatest single handicap in boundary lubricant research has been the lack of tools in the form of accurate and reliable bench test equipment. The stark oversimplification of E.P. testing equipment contrasts sharply with the complexity of friction and wear phenomena. The Alpha Model LFW-1 is the result of a search for an "intermediate" between the oversimplified E.P. Bench Test and costly and time consuming full scale performance tests. Such intermediates, of which many are needed, cannot fail to sharply reduce the terrific waste of research expenditure and talent.

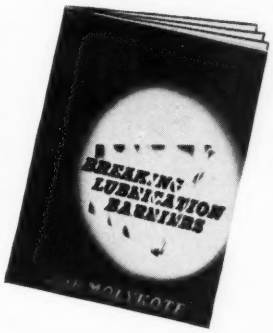
Since all E.P. lubricity ingredients function effectively only in a limited temperature range, E.P. Bench Tests must either measure frictional contact temperature or, pending the development of means to do so, simulate them. Sliding velocity is one important factor in this simulation. A large group of E.P. lubricity ingredients which are highly successful in industrial low velocity mechanisms completely fail to respond on most E.P. testers because excessive velocities and loads combine to produce frictional temperatures beyond the functional temperature range of the E.P. ingredient.



Alpha Model LFW-1 Lubricant-Friction-Wear Tester for sliding velocities below 43 feet per minute. Machine is designed for low velocity extreme bearing pressure applications. Developed by professional testing machine designers for an accuracy of better than 98% in load, velocity and friction measurements, results reflect the performance characteristics of a lubricant in a uniformly loaded and accurately defined friction area. The only variables from test to test are those intended by the operator.


MAXIMUM LOAD 630 LBS.
TEST BLOCK SPHERICALLY SEATED FOR UNIFORM LOAD DISTRIBUTION OVER ENTIRE LINE CONTACT AREA
FRICTION LOAD PICK-UP
TIMKEN TEST RING
FRICTION FORCE AT LINE OF CONTACT DIRECTLY TRANSMITTED TO LOAD PICK-UP
FRICTION LOAD INDICATOR

If you have a really important lubrication job to do involving extreme pressures or extreme temperatures, try MOLYKOTE Lubricants. Send today for complete application data and your copy of "Breaking Lubrication Barriers . . . with MOLYKOTE".



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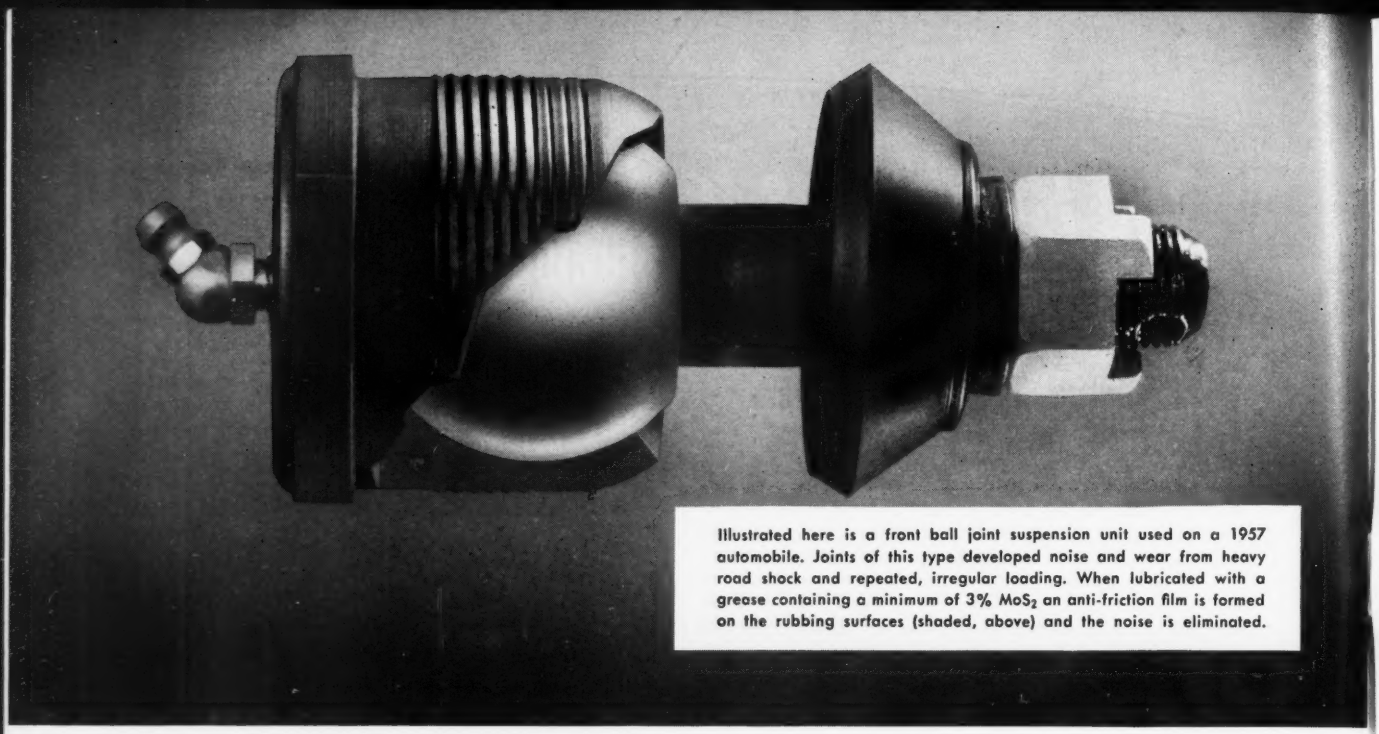
The ALPHA MOLYKOTE Corporation

MAIN FACTORIES: 65 Harvard Avenue, Stamford, Conn.
71 Arnulfstrasse, Munich 19, Germany



Illustrated here is a front ball joint suspension unit used on a 1957 automobile. Joints of this type developed noise and wear from heavy road shock and repeated, irregular loading. When lubricated with a grease containing a minimum of 3% MoS_2 an anti-friction film is formed on the rubbing surfaces (shaded, above) and the noise is eliminated.

When bearing surfaces are stripped of lubricants by SHOCK LOADING, OSCILLATION or RECIPROCATION . . .

MOLY-SULFIDE additive extends effective lubrication

Serious lubrication problems are often set up by extreme pressures, shock loading, oscillation and certain forms of reciprocating motion. Conventional lubricants may be forced out of the bearing area or wiped off the bearing surface. Then something more than a standard grease is required.

In situations of this kind, grease containing Moly-Sulfide proves its great value. MoS_2 is forced between the rubbing surfaces, adheres to the metal and forms a protective film that prevents galling, welding and fretting. The extent to which MoS_2 sustains lubrication is demonstrated by substantial reduction in wear, and is borne out by field reports from many different industries.

4 specific cases show advantages of MoS_2 for industry

Avoids splitting in steel punching. For example, while punching 5/8" holes in 1/2" thick hot rolled steel it was found that splitting of the plate frequently occurred between two adjacent holes, or toward the edge of the plate. This trouble, a result of heavy shock loading, was eliminated by brushing punches with lubricant containing MoS_2.

Makes excellent break-in lubricant for rocker arms. For break-in runs of engines, one of the major automobile manufacturers uses a supplemental MoS_2 grease on rocker arm pivots. The MoS_2 provides a low-friction film when the base lubricants wipe off under oscillating motion. This prevents galling and scoring of the mating surfaces.

Gives smooth travel to 4-ton grinding head. On a heavy cylindrical grinder the 4-ton head moves on the ways in a jumpy fashion, resulting in damage to the work. Use of a lubricant containing MoS_2 results in smooth, precise travel.

Serves well where lubricant cannot be resupplied. Moly-Sulfide is now widely used for lubricating such hard-to-reach points in automobiles as convertible top mechanisms, power operated windows and seat adjusters. Applied at assembly, the MoS_2 extends lubrication and greatly reduces noise and wear.

Many manufacturers now producing MoS_2 greases

Moly-Sulfide greases are available from many producers today. For a list of the manufacturers of these greases (Lu-2a) – which includes several major oil companies – and for a copy of "Molybdenum Disulfide as a Grease Additive" (Lu-17) write to Department 38, Climax Molybdenum Company, 500 Fifth Avenue, New York 36, N. Y.

TRABON

CENTRALIZED LUBRICATION

Giant ore bridge buckets dig and load 17% more with Trabon lubrication

Now, lubricating this giant ore bridge bucket is simple and economical! All a man does is to connect a very inexpensive grease gun to a Trabon heavy duty feeder. All 40 bearings then receive the exact measured amount of grease they need in a matter of minutes. Downtime for lubrication is cut from 45 minutes to less than 5 minutes. Digging and blast furnace loading time is increased 17% each 8-hour day. Lubrication is now safe, dependable and positive since Trabon Centralized Lubrication Systems were installed at this Midwestern steel plant three years ago on three giant ore bridge buckets. Write today for further information.

Close up shows Trabon feeder system operating on one of three similarly equipped ore bridge buckets. All industry relies on Trabon for positive lubrication under rugged conditions.

Trabon

Trabon Engineering Corporation

28787 Aurora Road • Solon, Ohio

Centralized OIL AND GREASE SYSTEMS *Mastoflo* CIRCULATING OIL SYSTEMS

Top Flight Lubricants

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